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JOURNAL OF THE

# BOSTON SOCIETY OF CIVIL ENGINEERS

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JOURNAL OF THE

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Volume XXXIV JULY, 1947 Number 3

# EXTENSION OF METROPOLITAN DISTRICT WORKS: WHAT'S ACCOMPLISHED AND WHAT'S AHEAD

By Karl R. Kennison*

*(Presented at a joint meeting of the Boston Society of Civil Engineers and the Northeastern Section of the American Society of Civil Engineers, held on April 16, 1947.)*

The Metropolitan District Water Supply Commission was created in 1926 for the purpose of constructng a major extension of the Metropolitan District water supply system. The work involved development of new areas on the Ware and Swift rivers adding 283 square miles to the District's watersheds and multiplying the safe yield of its sources by about 2¾. When the development of these new sources was practically completed, the legislature continued the life of the Commission as an organization for heavy construction work by giving it other tasks, such as the design and construction of a new pressure aqueduct to bring the water to the Metropolitan area and the design and construction of numerous additions to the Metropolitan sewerage works. Various phases of the Commission's activities have been described in the technical press and the writer will try to avoid repetition in summarizing the work, and furthermore will confine his comments to items of major interest.

The accompanying condensed bibliography will enable one to refer to the more important reports on which the enabling legislation was based, to the various statutes which have provided the authorizations, to the more important reports which have recommended further extensions, to the public documents which present the official record of the Commission's work, and to some of the more comprehensive papers which have been published by local and national engineering societies.

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*Chief Engineer, Metropolitan District Water Supply Commission, Boston, Mass.

So far as appropriation of money is concerned, the construction work is divided into four main parts: the Southern Sudbury Emergency Supply practically completed in the first year of operations under a separate appropriation, the Quabbin Development and all other water supply improvements paid for by the Water District, and the Sewerage Projects paid for by the South Metropolitan Sewerage District and those paid for by the North Metropolitan Sewerage District.

## METROPOLITAN DISTRICT-WATER SUPPLY CONDENSED BIBLIOGRAPHY

Some of the more important reports on which the enabling legislation covering the work of the Metropolitan District Water Supply Commission was based, and the enabling acts, are:

Report of the Joint Board Consisting of the State Department of Public Health and the Metropolitan District Commission Relative to Water Supply Needs and Resources of the Commonwealth.—Mass. Legislative Document Ho. 1550, 1922

Creation of the Metropolitan District Water Supply Commission and Authorization to Construct the Ware River Diversion.—Chapter 375, Acts 1926

Authorization to Construct the Quabbin Reservoir and Complete Quabbin Aqueduct.—Chapter 321, Acts 1927

Report of the Metropolitan District Water Supply Commission upon the Use of the Southern Sudbury and Cochituate Sources of Water Supply for the Metropolitan District, etc.—Mass. Legislative Document Ho. 221, 1927

Authorization to Construct the South Sudbury Emergency Supply.—Chapter 111, Acts 1927

Special Report of the Department of Public Health and the Metropolitan District Water Supply Commission Relative to Preventing Pollution of Water Supplies of Worcester and the Metropolitan Water District.—Mass. Legislative Document Ho. 402, 1932

Authorization to Construct the Rutland-Holden Trunk Sewer.—Chapter 262, Acts 1938

Authorization to Construct Holden Sewer System with Federal WPA Labor.—Chapter 286, Acts 1939

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Special Report of the Metropolitan District Water Supply Commission and the Department of Public Health Relative to Improvements in Distribution and to Adequate Prevention of Pollution of Sources of Water Supply of the Metropolitan Water District.—Mass. Legislative Document Ho. 262, 1938

Authorization to Commence Construction of Pressure Aqueduct.—Chapter 460, Acts 1938

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Authorization of Extensions and Additional Appropriation.—Chapter 515, Acts 1946

Report of Special Commission Investigating Systems of Sewerage and Sewage Disposal in the North and South Metropolitan Districts.—Mass. Legislative Document. Ho. 2465, 1939

Authorization of the Enlarged Commission to Construct Five Sewerage Projects with Federal Aid.—Chapter 720, Acts 1941

Same, with Elimination of Federal Aid.—Chapter 705, Acts 1945

Additional Appropriation for the same.—Chapter 446, Acts 1946

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Other miscellaneous legislative documents containing the latest proposals to extend the Metropolitan Water System to new districts, are:

Report of the Special Commission to Investigate Relative to Certain Problems in the Merrimack Valley. Senate 100, 1938

Report of the Special Commission to Investigate Relative to the Water Supply Needs of Municipalities in the Connecticut, Chicopee, Swift, Ware, Quaboag and Millers River Valleys.—House 1667, 1947

Reports currently published in Public Documents, which have to do with the Metropolitan District, are:

Annual Reports of the Metropolitan District Commission.—P. D. 48

Annual Reports of the Metropolitan District Water Supply Commission.—P. D. 147

Annual Assessments for Interest, Sinking Funds, Serial Bonds and Maintenance of the Metropolitan Districts.—P. D. 92

Some of the more comprehensive papers on the work of the Metropolitan District Water Supply Commission published by various engineering organizations, are:

Subsurface Explorations for the Location of the Wachusett Swift-Tunnel, by Frank E. Fahlquist.—BOSTON SOCIETY CIVIL ENGINEERS JOURNAL, January, 1929

Diamond Drill Borings for the Swift River Dams, by N. LeRoy Hammond.—BOSTON SOCIETY CIVIL ENGINEERS JOURNAL, January, 1929

The Metropolitan District Water Supply Tunnel from the Ware River to the Wachusett Reservoir, by Frank E. Winsor.—BOSTON SOCIETY CIVIL ENGINEERS JOURNAL, November, 1932

Design and Progress on Construction of Dams for Quabbin Reservoir, by Stanley M. Dore.—BOSTON SOCIETY CIVIL ENGINEERS JOURNAL, July, 1935

Quabbin Reservoir—Recent Developments in the Construction of the Ware-Swift Water Supply for the Metropolitan District, by Frank E. Winsor.—BOSTON SOCIETY CIVIL ENGINEERS JOURNAL, July, 1938

Design of Plate Steel Tees, Laterals and Wyes for the Pressure Aqueduct of the Metropolitan Water District, By Chester J. Ginder and Edwin B. Cobb.—BOSTON SOCIETY CIVIL ENGINEERS JOURNAL, April, 1941

The Hydraulics of the New Pressure Aqueduct of the Metropolitan Water District, by Karl R. Kennison.—Boston Society Civil Engineers Journal, January, 1942

Symposium on the Boston Metropolitan District Development and Administration, etc.—American Society Civil Engineers Proceedings, December, 1929

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Diversion of Interstate Waters for Domestic Water Supply. Litigation and U. S. Supreme Court Decision in Case of Connecticut vs. Massachusetts, by Frank E. Winsor.—New England Water Works Association Journal, September, 1931

Boston Metropolitan Water Supply Extension, by Karl R. Kennison.—New England Water Works Association Journal, June, 1934

Metropolitan Water Supply Distribution System, by Eugene C. Hultman.—New England Water Works Association Journal, June, 1938

Real Estate Acquisitions for Metropolitan Boston's Water Supply in the Swift River and Ware River Watersheds, by James A. Christenson.—New England Water Works Association Journal, June, 1940 and June, 1945

Design and Construction of Pressure Aqueduct for Boston Metropolitan District, by Stanley M. Dore.—New England Water Works Association Journal, September, 1941

Water Charges to the Municipalities by the Metropolitan District Commission, and Metropolitan Water District Financing, by Karl R. Kennison—New England Water Works Association Journals, December, 1941 and June, 1946

Water Supply Developments in Boston, by Karl R. Kennison.—New England Water Works Association Journal, September, 1946

Reforestation of Quabbin Watershed, by Russell Snow.—New England Water Works Association Journal, March, 1947

The Character of Quabbin Reservoir Water During Reservoir Filling, by Clarence H. Reed.—New England Water Works Association Journal, June, 1947

Disposal Plant to Alleviate Boston Harbor Nuisance, by Karl R. Kennison.—Civil Engineering Magazine of American Society Civil Engineers, June and July, 1946

Proposed Improvements in Sewage Disposal and Treatment in the Boston Metropolitan District, by Karl R. Kennison—Sewage Works Journal of the Federation of Sewage Works Associations, January, 1945

A General Description of the Water Supply, published by the Commission in celebration of the first discharge of water through Hultman Aqueduct, Oct. 23, 1940.

## The War Department Permits

One of the first hurdles which the Commission had to top was that of the War Department's concern over navigation. Neither the Ware and Swift rivers from which the new supply was taken nor the Chicopee River into which they flow are navigable. However, the Chicopee flows into the Connecticut River which is navigable by large tonnage as far upstream as Hartford and by small boats and pleasure craft to Springfield. On January 25, 1927, the District Engineer of the War Department requested data on the new supply, and on November 22 of that year ruled that the work must be contingent upon War Department permits. The Commission filed applications without delay on November 30, and the War Department after a public hearing on February 9, 1928, issued, on March 19, a permit for the Ware diversion and therein notified the Commission that "no objections will be interposed by the War Department to the diversion of the flood waters of the Ware River exceeding 85 million gallons daily for the period October 15 to June 15 each year." This diversion limit is about 1.36 c.f.s. per square mile, and the same as provided by Massachusetts legislation. The Commission then proceeded with the excavation of the Quabbin Aqueduct tunnel westerly from Wachusett Reservoir to the Ware River.

The War Department took an additional year to consider the case of the Swift Supply, and on May 17, 1929, issued a permit for the Swift diversion by notifying the Commission that "there will be no substantial alteration or modification of the condition or navigable capacity of the channel of the navigable portion of the Connecticut River if the flow . . . . . be augmented during the critical period from June 1 to November 30", by releases which would make the total release 70 c.f.s. on days when the flow in the Connecticut River at Montague City is less than 4,900 and 110 c.f.s. when such flow is less than 4,650 which is a little less than 0.59 c.f.s. per square mile. Although these restrictions by the War Department on the Ware and Swift diversions would theoretically make a slight reduction in the net safe yield available for water supply, actually there is at present a surplus of water and the turbine being installed at Winsor Dam will discharge this daily into the river. In the meantime, additional storage facilities are being continually added on the head waters of the Connecticut River which will make a decided improvement in dry weather flows on the lower Connecticut long before the District's water consumption reaches the safe yield of the Quabbin system.

### Connecticut Case

The Commission felt that the War Department's permit for the Ware supply justified their proceeding with the sinking of shafts for the Quabbin Aqueduct, particularly in view of the importance of getting the tunnel started so that the Ware supply could be made available at the earliest opportunity. However, the awarding of the contract for the tunnel itself was delayed by objections raised by the State of Connecticut. On July 11, 1927, the Attorney General of Connecticut had requested information on the project and on January 16, 1928, filed with the Supreme Court of the United States a bill of complaint objecting that the proposed interstate diversion would impair navigability of the Connecticut River, would take away flood waters and thereby damage agricultural lands subject to yearly inundation, would lessen the scouring effect which prevents the river from becoming a nuisance and a menace to public health, etc.

The answer of Massachusetts was filed promptly on March 5, 1928, and subsequently amended on the basis of the War Department's permits. After various motions and denials, Connecticut filed its reply on January 27, 1930, stressing the claim that the Metropolitan District could obtain an adequate supply in eastern Massachusetts without the necessity for making any diversions from the Connecticut River. The hearings were before the Special Master, Charles W. Bunn, Esq. Evidence was taken in Boston and Hartford, February 18 to March 21, 1931, and arguments before the Master in St. Paul, Minnesota, April 23 and 24, 1930. The Master's report on May 19, sustained the position of Massachusetts, and on October 6, Connecticut filed exceptions. Massachusetts filed none but both states submitted briefs on Connecticut's exceptions. On January 5 and 6, 1931, the case was argued before the Supreme Court in Washington, D. C., on the exceptions. On February 24, the opinion of the Court in this case was delivered by Justice Butler. Some of the more important decisions in this momentous case are as follows:

The Master found "that the people of Massachusetts have decided against the eastern water supplies by passing the Ware and Swift legislation. These acts were the result of long-continued and careful study." He stated, "I think these investigations and the legislative acts show a public sentiment against the eastern water supplies and make a prima facie case that these supplies are inadvisable, either because inadequate or unfit", and continued "Our governments in the long run are controlled by public opinion. And while an expert on water, acting in a strictly professional capacity, may say that he will disregard public opinion, municipal and other governments cannot take that stand. The courts it seems to me cannot close their eyes to the necessities imposed by public opinion on governments." He took note of the fact that "It may be suggested that Massachusetts has lost rights which she otherwise might have had by having herself allowed her eastern waters to be polluted; and that she cannot profit by a necessity for Ware-Swift water which she has created", but concluded "However, her practice has not been different from that of Connecticut and other New England states and it is a matter of notoriety that it is not different from the practice which has prevailed on other rivers and in other parts of our country. The pollution of our country's rivers makes a pitiable record. I think Massachusetts should not be penalized in this fashion for following a practice which has been almost or quite universal in the United States."

The Supreme Court found that "There is nothing in the Master's findings of fact to justify an inference that any real or substantial injury or damage will presently result to Connecticut from the diversions by Massachusetts authorized by the Acts of 1926 and 1927 as limited and defined by the Secretary of War", and that "Drinking and other domestic purposes are the highest uses of water. An ample supply of wholesome water is essential. Massachusetts, after elaborate research, decided to take the waters of the Ware and Swift rather than to rely on the sources in the eastern part of the Commonwealth where all are or are liable to become polluted. We need not advert to other considerations, disclosed by the evidence and findings, to show that the proposed use of the waters of the Ware and Swift should not be enjoined." The Court concluded that "Connecticut's Bill of Complaint will be dismissed without prejudice to her right to maintain a suit against Massachusetts whenever it shall appear that substantial interests of Connecticut are being injured through a material increase of amount of the waters of the Ware and Swift diverted by or under the authority of Massachusetts over and above the quantities authorized by the Acts of 1926 and 1927 as heretofore limited by the War Department."

For a more complete digest of the Connecticut case one should refer to a very complete paper by former Chief Engineer Frank E. Winsor published in the Journal of the N.E.W.W. Assoc. for September, 1931, and also to the scholarly companion paper on the Law of Interstate Waters by the Commission's former consulting engineer Thaddeus Merriman published in the same issue of the Journal.

## QUABBIN RESERVOIR

The new work involved principally a new storage reservoir in the Swift River valley which has been named Quabbin Reservoir for the old Indian Chief Quabbin, who was interested mainly in fishing but who never anticipated that the white man, who crowded him out, would some day be interested in fishing on such a large scale. The most unusual thing about this reservoir is that the Metropolitan District, in which people are crowded about as closely together as anywhere in the United States, could find, only 65 miles from the State House, a watershed occupied by only 21 people per square mile, and containing a site so ideally suited to the construction of a water supply reservoir. The size of Quabbin is probably unprecedented among reservoirs devoted entirely to domestic water supply. It has a water surface of 38.6 square miles at Elevation 530 feet above Boston City Base or mean low tide. Above the original surface contours, the capacity is 412.3 billion gallons and although the point at which water

VIEW OF QUABBIN RESERVOIR FROM THE SCENIC HIGHWAY is drawn to supply the District is located seven miles above the main dam, the site is so ideally contoured that only 10 billion gallons of the total is unavailable below the sill of Quabbin Aqueduct. The undulating bed of the valley contains such extensive areas of porous sand and gravel that ground storage is taken into account in reporting data on the available supply. The total available for draft to the District is estimated to be well above 415 billion gallons.

## Real Estate Acquisitions

One outstanding feature of the work is the great size of the Quabbin reservation, and the fact that the District could acquire it with little difficuty. The operations of the Commission resulted in a general increase in tax valuations of not over 40 per cent, and the Commission acquired the very large reservation at an average cost per acre of about $90 net, to which $20 should be added to cover overhead, legal and all other costs properly chargeable to the real estate account. The price paid per acre varied with the type of property, roughly as follows: for residential property $3500, recreational property $600, farm property $80, woodland property $28.

Mere figures do not do justice to the size of the area. To say that about 80,960 acres were acquired in the Swift Valley, as of the end of the last fiscal year, and about 21,100 more in the Ware Valley, does not mean as much as to say that this area is 10 per cent more than that of all the 20 cities and towns in the Metropolitan Water District. There certainly can be no doubt that the Commission has avoided the mistakes of earlier development of the District's storage reservoirs by purchasing and controlling an ample area for sanitary protection. Nevertheless a cost comparison with water supply developments of other large Metropolitan areas is quite favorable to ours. Including actual purchases and settlements and other costs chargeable to the real estate account, New York City spent, for its Catskill supply, a little over $104 per million gallons of storage capacity. Providence, for its Scituate supply, spent a little over $125. Massachusetts spent, for its Wachusett supply, about $49. The Commission has spent for the Quabbin supply on account of real estate including both the Ware and Swift watersheds only about $27 per million gallons of storage capacity. Even taking account of the relative over-sizing of the reservoir with respect to safe yield, the cost comparison is still favorable.

One interesting feature in connection with the real estate settlements is that although takings by eminent domain were made to protect the title, the actual settlements were in most cases the result of agreements with the owners. These were encouraged to offer their property for sale. The Commission then had appraisals made by disinterested experts, and in general the price paid was about 70 per cent of the owner's original offer. The entire matter of the real estate acquisitions is covered in excellent fashion in papers by our former real estate engineer, James A. Christenson, published in the Journals of the New England Water Works Association for June, 1940 and June, 1945.

After most of the property in Quabbin Reservoir had been acquired, a single taking by eminent domain was recorded on March 28, 1938, which broke all records so far as the extent of area and other features were concerned. It covered 74,886 acres in 12 towns and 3 counties, and required 21 plans and 97 typewritten pages. Incidentally it was this taking which established the date, 30 days after the recording, when the four towns Dana, Enfield, Greenwich and Prescott were, under the legislative provisions, wiped out of corporate existence.

## LIQUIDATION OF TOWNS

The liquidation of entire townships was one of the unprecedented features of the Commission's work. It introduced many unique problems not only on account of the legal necessity for maintaining the rights of the individual citizens of these towns, but also on account of the great area covered. As a result, the Commission had to assume many roles: of school teachers, welfare agents, fire marshals, undertakers, and many others, in the liquidated towns of Dana, Enfield, Greenwich and Prescott.

The criterion which was followed in dividing up the area for annexation to the adjoining towns and counties was to extend the existing town lines in all cases, except for one minor exception, so that they intersected the thread of the stream at one of the original main branches of the Swift River, in such a way that in the future the jurisdiction of each town will extend to the water line of the reservoir regardless of the extent to which the water level in the reservoir may be drawn down. As a result, the 47,667 acres in the four towns and three counties were realigned so that there was a net gain in area to Franklin County of 17,959 acres and to Worcester County of 7,312 acres, with a corresponding net loss to Hampshire County of 25,271 acres. Of the surrounding towns, Petersham received the largest increment, 18,837 acres; New Salem, 17,959; Ware, 7,197; Belchertown, 1,699; Pelham, 1,368; and Hardwick, 607.

The population of the four liquidated towns was 2,086 according to the 1925 census. As a result of the exodus this had decreased to 1,378 in 1930, and to 1,119 by the census of 1935, the last one taken before the liquidation. The exodus continued and for the purpose of the statistical record, it is estimated that in the dividing up of area and the annexation to six adjoining towns this last recorded population was distributed as follows::

| | *Population by 1935 census* | *Increased by* | *Resulting Total predated as of the 1935 census* |
|---|---|---|---|
| Belchertown | 3,863 | 40 | 3,903 |
| Hardwick | 2,379 | 22 | 2,401 |
| New Salem | 443 | 340 | 783 |
| Pelham | 504 | 15 | 519 |
| Petersham | 718 | 527 | 1,245 |
| Ware | 7,727 | 175 | 7,902 |
| | | 1,119 | |

## RELOCATION OF CEMETERIES

The removal of bodies from the reservoir area has been one of the most extensive operations of the Commission, and one that has brought it into the closest contacts with the public. It is the only extensive operation that could be classed as construction, which was not done by contract. At one time there were several thriving industrial and farming communities in the Swift Valley. The population of many a town in this vicinity before the Civil War was more than double what it was when the Commission entered the valley. Many of the burials were very old and one of the exacting features of the removal work was the location of living representatives interested in the remains. No removals were made without first giving some interested representative an opportunity to be present. In case no representative could be found, the removal involved even more care on account of the necessity for preserving all available information in anticipation of later contacts with relatives of the deceased. On this account every clue regarding the identity of bodies has been preserved.

All work of removal was performed by a selected labor force at regular labor rates, and the only real difficulty and hazard was in the handling of large and sometimes fragile monuments. For a considerable time after the work was first organized, the Commission received letters from widely scattered points which indicated that some enterprising newspaper reporter had made up out of whole cloth a story to the effect that the excavations in the old cemeteries would be difficult and gruesome work for which wages would be paid at several times the rate for common labor, that applicants would be selected from those best qualified physically and mentally, and that all would have to be quarantined and sign an agreement to stay on the job. This story was apparently repeated in many small-town papers in the eastern United States and Canada, and kept cropping up for a period of over ten years. In one instance two men walked several hundred miles to make application. The writer remembers distinctly a letter received from a woman who wanted to get her lazy husband on the job.

Thirty-five cemeteries were abolished. 7,606 bodies were removed and of this total, 1,010 were reinterred in more remote existing cemeteries designated by the interested parties. The remaining 6,596 were reinterred in the new cemetery which the Commission constructed in the Town of Ware, and named Quabbin Park Cemetery. In addition nearly 300 burials have had to be made on account of deaths that have occurred since August 25, 1932, when the old cemeteries were closed by order of the Commission.

Quabbin Park Cemetery is attractively situated on Route 9 just south of Quabbin Reservoir. It was originally laid out in lots of eight graves each and provided for approximately 12,000 burials. The development contains a water supply system, about 4,500 feet of driveways giving easy access to each lot, and a vault for winter storage. A central building is for the convenience of the public as well as for storage in connection with maintenance. One feature of this development was the inclusion of public memorials of the four discontinued towns, such as monuments of the Civil War and World War I. The pride which has justly been taken by the Commission in this work apparently was sufficiently contagious so that the legislature amended the original statute which provided that the cemetery be turned over to the Town of Ware, so that it will continue to be held by the Commonwealth and maintained by the Metropolitan District.

The following interesting inscription, copied from a headstone in one of the cemeteries in Pelham Center which had to be partly re-located, is typical of a few quaint opinions engraved in the old cemeteries in the reservoir area:

WARREN GIBBS
DIED BY ARSENIC POISON
MAR. 23, 1860
AGE 36 YRS. 5 MOS.
23 DYS.

THINK MY FRIENDS WHEN THIS YOU SEE
HOW MY WIFE HATH DEALT BY ME
SHE IN MY OYSTERS DID PREPARE
SOME POISON FOR MY LOT AND SHARE
THEN OF THE SAME I DID PARTAKE
AND NATURE YIELDED TO ITS FATE
BEFORE SHE MY WIFE BECAME
MARY FELTON WAS HER NAME

ERECTED BY HIS BROTHER
WM. GIBBS

## Relocation of Highways and Public Utilities

The isolated character of the reservoir site made it possible not only to acquire ownership of a very large reservation, but also simplified the problem of relocations. A total of 242 miles of public highways were abandoned. In substitution, the Commission with the cooperation of the Department of Public Works built nearly 36 miles of hard-surface highways which were turned over to the Department to be operated as State highways. Of these relocated highways the first to be built ran east and west just below Winsor Dam and Quabbin Dike. This new location of Route 9, between Ware and Amherst, eliminated the loop which extended northerly to serve the former village of Enfield.

Travel north and south formerly followed old Route 21 between Belchertown and Athol serving the valley towns of Enfield, Greenwich and Dana, and paralled the Athol Branch of the Boston & Albany Railroad. As a result of extensive surveys and appraisals, we were able to make a settlement with the railroad, satisfactory to both parties, by which not only the 15.8 miles of track below the flow line but the entire Athol Branch between Bondsville and Athol was abandoned and the necessity for relocation avoided. Although the case was actually taken into court by the railroad, this was only on account of delays caused by failure to obtain the approval of the Governor and

Council of the terms of the settlement, and the court award merely added to the original agreement interest accumulated during the delay. The total sum paid was less than one-quarter of the figure included in the original estimates to allow for the possible necessity for relocation.

It was partly in consideration of the abandonment of the railroad that the Commission agreed to construct a north-south highway west of the reservoir which would be adequate to carry all through traffic between Springfield and Athol, including heavy truck handling of freight. This highway is now part of Route 202, the main artery between New York and the White Mountains and the section which we constructed has been named the Daniel Shays Highway after the instigator of Shays' Rebellion in old Pelham. The Commission constructed another main east-west highway north of the reservoir, now a part of Route 122 between Worcester and Orange. There was no necessity for constructing a main north-south thoroughfare on the east side of the reservoir as all local needs were adequately served by the reconstruction of a short length of the county highway between Dana and Petersham.

In addition to these roads built as substitutes for abandoned highways, the Commission constructed other hard-surface roads to meet its own requirements for access. These included a scenic road between Winsor Dam and Quabbin Dike from which the public can get unsurpassed views of Quabbin reservoir. This road passes the Winsor Memorial which overlooks the dam and spillway channel and is a very attractive feature of the scenic highway. This memorial to the former Chief Engineer of the Commission was erected by Mr. Winsor's many friends and sponsored by the Boston Society of Civil Engineers and the Northeastern Section of the American Society of Civil Engineers. It was dedicated June 17, 1941. A branch highway extends to a large parking area near the top of Quabbin Hill from which it is only a short walk to an observation tower from which a splendid view can be had and which also serves as a fire lookout.

The Department of Public Works contributed toward the cost of construction of all highways turned over to it as State highways, a sum sufficient to cover the items of surfacing. There were six contracts for such State highways numbered 21, 41, 43, 44, 55 and 57. The total of such contributions aggregated $582,047.

A number of public utility lines had to be relocated for the reser-

The Winsor Memorial on the Scenic Highway Dedicated June 17, 1941

voir. The most important of these was the 66,000-volt transmission line of the New England Power Company which was moved from its former crossing of the Swift River just below Enfield to a new 8.5-mile location skirting Winsor Dam. A 110,000-volt line of the same company crosses the reservoir near its upper end but by a minor alteration at the foundations of the steel towers the necessity for relocation was avoided.

## Winsor Dam and Quabbin Dike

In order to impound the water in Quabbin Reservoir, it was necessary to construct two large dams with deep foundations. These were necessary to close two pre-glacial valleys which had been filled to great depths with irregular deposits of washed material sufficiently porous to require a water cut-off to sound ledge. Although only one of these valleys is occupied by the present Swift River, they are both of approximately the same dimensions as far as the bed rock is concerned. The following tabulation shows the principal dimensions of these two important dams:

| | *Winsor Dam* | *Quabbin Dike* |
|---|---|---|
| Height above the lowest ledge surface | 295 feet | 264 feet |
| Maximum height above the stream bed | 170 feet | 135 feet |
| Maximum depth of water below the flow line | 150 feet | 115 feet |
| Length at the top or road level | 2,640 feet | 2,140 feet |
| Number of cubic yards above original surface | 4,000,000 | 2,500,000 |

First Water Over Winsor Spillway June 22, 1946

Some previous experience in the sinking of a row of caissons to form a cut-off wall was available from the construction of the Wyman Dam of the Central Maine Power Company. For the two structures at Quabbin, this plan was carried further by the preliminary lowering of the ground water level to reduce the amount of work necessary to be done under compressed air. This illustrates in excellent fashion a typical procedure on much of the Commission's work, namely liberal expenditures for preliminary investigations, studies and design charged to the engineering account, in order to lessen the Contractor's risk. In this case, the Commission sank under a preliminary contract an exploratory caisson at each of the two dam sites and also lowered the ground water by pumping for a year or more in advance of the main contract work. As a result of this method of doing the work, 1,418 vertical feet of caisson sinking at Winsor Dam, and 1,402 feet at Quabbin Dike were done in free air, which otherwise would have required compressed air, and only a relatively small sinking depth of 60 feet at the Dam and 38 feet at the Dike had to be done under air pressures in excess of 18 pounds, per square inch, the legal limit for working full 8-hour shifts. Foundations by the conventional open-cut method would have cost three times as much.

No problem was involved in taking care of the flow of the small brook past the site of Quabbin Dike since the local drainage area involved was only 1.6 square miles. To divert the Swift River past the site of Winsor Dam, it was necessary to construct a diversion tunnel 30 feet wide, 28 feet high and 1,230 feet long through sound ledge under the southwest abutment, in order to make sure that the construction of the Dam would be completed expeditiously and all risk of damage from floods eliminated. One very interesting, and in fact unique, feature of the design was the use of a siphon to carry the entire low flow of the river during the final operation of permanently plugging the tunnel. The upstream leg of this siphon was embedded in the tunnel lining and left undisturbed. The downstream leg was designed to be later converted for use as a part of the main penstock from the bottom of the permanent intake gate well to the outlet works downstream. The central or temporary portion was constructed of 36″ cast-iron pipe conveniently located in the dry well above the plugging operations. The vacuum was created without difficulty by means of a small air pump and maintained itself automatically. At the conclusion of the operation this entire central section was broken out and removed, and the space entirely enveloped in the solid concrete plug. This procedure eliminated any precarious work to make the final closure in close quarters below the water level.

At the outlet end of this stream diversion tunnel is located the control works in which we are now engaged in installing a hydroelectric plant to take advantage of the available head and of the discharge which must be released to the river below. A single unit is being installed in a vertical-shaft setting, having a capacity of 1700 horsepower. This is capable of making economical use of the daily minimum release concentrated in the hours when most useful, of the maximum continuous release required under any stipulations of the War Department, and what would otherwise be unavoidable spillway waste over a period of many years. The power developed in this manner is not commercially valuable except as an increment to the load on a large and flexible system. Accordingly it will be sold to the New England Power Company at the price agreed, for the greater bulk of the energy developed, of 6.25 mils. In these control works provision is made for taking off an aqueduct line for any future local water supply needs that may develop, such as the supplying of towns in the Chicopee Valley. The first portion of the Winsor Dam embankment to be built was the upstream cofferdam constructed of the material excavated from the river diversion tunnel and from its extensive portal cuts. This cofferdam built to a height of 50 feet above the bed of the river together with a much lower downstream cofferdam completed the unwatering of the dam site.

The embankment of each of the two dams was constructed first by filling around the top 25 feet of the caisson core wall with rolled impervious soil to a sufficient extent to no longer require the ground water level to be depressed. The main embankment was then constructed by the full-hydraulic method which consists of sluicing selected material to the site allowing the coarser gravel and sand to build up the upstream and downstream shoulders, and the finest material to be washed into the central pool to settle slowly and to form the impervious core. This method of construction is well-known and there were no unusual features except that it was possible by selecting the proper borrow pits as the work progressed to obtain an ideally graded material, coarse enough to give well drained shoulders and containing very little excessively fine material such as true clay. The resulting core was sufficiently impervious, yet drained and consolidated at a rate which not only insured stability throughout the period of construction but also an ideally compact structure. One minor innovation might be mentioned, namely the construction of three inspection wells, two in the Dam and one in the Dike, consisting of 36″ steel cylinders with observation ports 8 feet apart staggered to look alternately upstream and downstream. From these ports, samples of the core material were taken to check the rate of consolidation.

Concise presentations of important data on the construction of the Winsor Dam and Quabbin Dike can be found in papers presented by Assistant Chief Engineer Stanley M. Dore to the Boston Society of Civil Engineers and published in that Society's Journal for July, 1935, and presented to the American Society of Civil Engineering and published in its Proceedings for March 1936 and September, 1937.

For the release of water to the river and for local water supplies that may be taken off at Winsor Dam, provisions have been made for manipulating shutters from the floor of the Inlet Works building to draw water at a depth of about 100 feet, about 60 feet, or at any depth within 30 feet of the surface.

## Clearing and Reforestation

Final clearing below the flow line was done under five contracts executed in October, 1938, one year before the start of filling the reservoir. These covered the entire area except for an experimental area, which we cleared by force account as a demonstration before bids were opened. The commission had previously cooperated in an unemployment relief clearing project undertaken by the commonwealth in 1936 on which about 4300 men were employed and $1,840,000 spent including some still being paid as compensation for injuries to inexperienced axemen. Clearing above the flow line was generally confined to the elimination of food species favored by growing gypsy moths, caterpillars.

One feature of the Commission's activities, the program of reforestation, is particularly interesting on account of its size. It also involved procedures in nursery work and broad planting which were interesting but more or less routine. This work extended over the last 12 years from 1935 to 1946 and in that time a total of about 10,200,000 trees were planted, with a survival of 85 to 90 per cent. In addition, the nursery beds yielded about 3,800,000 seedlings and 3,500,000 transplants which were surplus because of the shortage of labor the last few years. In the Swift watershed alone the total area planted was about 6200 acres. A most interesting account of this work was presented by the Commission's Forester Russell Snow before the New England Water Works Association and published in its Journal of March, 1947.

## QUABBIN AQUEDUCT

Quabbin Aqueduct brings the water from the new Quabbin Reservoir, with flow line at Elevation 530, to the old Wachusett Reservoir with flow line at Elevation 396.5. It was located so as to pass directly beneath the Ware River Diversion Works and the valves which control

WARE RIVER DIVERSION WORKS

the flow are located at the Wachusett end. The entire works were designed in such a way that the flood flows of the Ware River can be diverted by a vertical drop into the tunnel and made to flow westerly to an outlet on the Quabbin shore, and thence through a devious course involving long-time storage in the upper end of the reservoir. Although the entire work is being described in this paper in what might be called a hydraulic rather than a chronological order, the construction actually started at the east end in order to complete the so-called Wachusett-Coldbrook section of the tunnel and make the Ware diversion available as soon as possible. To hasten the work, contracts for the construction shafts were awarded first and progressed while two main tunnel contracts for this Wachusett-Coldbrook section were being prepared. As it worked out, both these tunnel contracts were assigned and became in effect a single contract which involved the largest sum in any contract of the Commission, namely $7,642,881. The subsequent extension of the tunnel to the east branch of Quabbin Reservoir was done under one contract including both shafts and tunnel, which amounted to $4,809,853. In all there were 12 shafts from which construction was carried on and another numbered 11-A, which is the uptake through which the flood waters of the Ware are delivered into Quabbin Reservoir.

At the time the tunnel was built, it was of unprecedented length. It is so long that if you stood at one end and had good enough eyesight to look through it horizontally, you would be looking at a point about 200 feet higher at the other end on account of the curvature of the earth. Although it is operated as a pressure tunnel, it was constructed for practically its entire length of the less expensive grade-line type. This was made possible because it is so deep underground that the natural ground water level is everywhere above the hydraulic grade inside the tunnel. The only important exception is for a distance near the downstream end and even here the cheaper grade-line construction was continued by lowering the invert so that the tunnel is everywhere embedded in 200 feet of solid ledge. Any outward leakage here merely finds a shorter route into Wachusett Reservoir and is unimportant.

A typical construction shaft was 14 feet in diameter inside the concrete lining and shaft depths varied from 200 to 656 feet. The procedure at each shaft head, particularly those in the watershed of a public water supply, was to purchase about 25 acres in order to find a sufficient area to dispose of the tunnel spoil, to create a basin for the collection and disinfection of the tunnel drainage from which local storm drainage had to be bypassed. The rock was generally sound and of igneous origin throughout the total length, varying from true schists to gneissoid granites. Only 1.52 per cent of the entire length required permanent timber support and only 0.41 per cent temporary support. The distance between shafts varied from about 8,800 to 16,700 feet and the headings met with an average divergence in the line of 0.42 foot, and an average discrepancy in the grade of 0.06 foot. A complete geologic record was kept as the work progressed and this is published in the Annual Report of the Commission for the year 1935. The tunnel was lined with concrete and was 11′ wide and 12′9″ high inside the lining. One unusual feature was necessitated by the fact that the east end, or Wachusett-Coldbrook section, was built first and put into operation for the diversion of Ware floods while the west half was being excavated. This required a massive steel bulkhead containing two swinging tide-gate doors of special design, and involved complications in the handling of water during the burning out and removing of the bulkhead.

Reverting again to the hydraulic instead of the chronological order, the Intake at Shaft 12 is designed so that, by the manipulation of shutters from the floor of the head house over Shaft 12, water can be drawn from an average depth of 83 feet through a submerged intake, extending out from the original tunnel portal. The entrance to this intake has an area of about 475 square feet most of which consists of 36 openings 1 foot wide between Elev. 442 and 454. Shutters also provide draft from any upper levels between the flow line and a depth of 44.67 feet.

At the Ware Intake over Shaft 8, the flood flows in excess of 85 m.g.d. are automatically diverted up to the capacity of the tunnel which is approximately as follows:

| | | |
|---|---|---|
| From Ware Intake to Quabbin Reservoir | 980 | m.g.d. |
| and simultaneously to Wachusett Reservoir | 1020 | ” |
| Total | 2000 | ” |
| From Ware Intake to Quabbin (none to Wachusett) | 600 | ” |

The full drop to the bottom of the shaft is about twice that over Niagara Falls. The shaft has a cast-iron lining with helical vanes. These vanes and the action of centrifugal force make the impact of a direct fall impossible and effectively dissipate the energy. On account of the friction loss in the tunnel, the higher the rate of diversion the less the drop at this shaft. For example in ordinary operation, 100 tons a second has a free fall of 120 feet; 500 tons a second, 75 feet.

At the top of Shaft 2 a spillway of unusual design prevents excessive head on the control works at Shaft 1 under any condition of operation. In the Wachusett Outlet Works Building at the top of Shaft 1, we are now preparing to install a 5,000-H. P. water wheel, under a contract which was delayed on account of the war. There will be a single vertical-shaft unit to utilize normally about 85 per cent of the drop of about 135 feet between Quabbin Reservoir and Wachusett Reservoir; the remaining 15 per cent being lost in friction in the 24.6-mile tunnel penstock. The arrangement with the New England Power Company to buy the power is similar to that at the Winsor Dam plant. However, the conditions of operation are most unusual on account of the impossibility of governing the flow in the long tunnel. The power company must absorb the power as it comes, with the turbine running wild, so to speak.

## WACHUSETT RESERVOIR

Quabbin Aqueduct discharges into the upper end of Wachusett Reservoir, which has been the main source of the District since its organization and since the reservoir was first filled in 1908. It has served the District remarkably well. It has a very clean bottom and over a year's storage and has continued to deliver water that is low in color and that has shown practically no deterioration in quality as yet, in spite of threats from increasing population close to the upper end of the reservoir. The commission has made preliminary plans for a branch line to divert sewage from West Boylston into the Rutland-Holden trunk sewer. The clearing up of this situation is one of the "musts" that lies ahead, but the actual accomplishment will have to wait until a town sewerage system is constructed to match the water supply system which the town recently installed.

The Quabbin-Wachusett reservoir system is the source from which the Metropolitan water system may be expanded to supply the needs of other areas or districts. The construction of new aqueducts for such purpose is more than a possibility. Special Legislative commissions have pointed out the desirability of supplying towns in the Merrimac Valley by an aqueduct extending northeasterly from Wachusett Dam and of supplying towns in and near the Chicopee Valley by an aqueduct extending southerly from Winsor Dam.

## The Need of the New Supply

The question has often been asked as to how badly the new supply was needed. It is natural to expect such a question from the taxpayer who sees water running to waste over the spillways of the District's storage reservoirs, because it is difficult to explain to the public the meaning of the safe yield of a watershed. The simple explanation is, of course, that public water supplies, such as that of the District, are designed to furnish water during the periods of drought. These are the only periods that count. There is always plenty of water at other times. The main criterion in designing the reservoirs is to make them large enough to hold flood waters when they do come, for distribution later during a period of drought.

This is well illustrated by the accompanying graph (fig. 1) which gives a concise record of the fluctuations in Wachusett Reservoir for the past 40 years, ever since it was first filled in 1908. During the early years when the rate of consumption was much lower than now, this reservoir had no difficulty in storing enough of the flood waters to take care of the dry seasons even though the entire period from 1908 to 1915 was definitely one of deficiency in rainfall and runoff. In fact this period was so dry that it still furnishes us the outstanding basic record for computations of safe yield of watersheds over a long term. Nevertheless in 1919 the Department of Public Health began to worry about the ability of the system to continue to supply the growing needs of the District; but the general public as represented by the legislature did not get sufficiently worried to authorize the new supply until faced with an actual drought in 1926. In spite of the fact that practically no new customers have been added in the last 40 years, the graph clearly shows that even as long ago as 1926, the consumption had increased to such an extent that this drought of only two years' duration produced a very severe drop in the reservoir level.

The legislature not only authorized the new supply from the Ware and Swift rivers, but recognized it would take many years to make it available and authorized the immediate construction of works that would make an emergency supply available from the South Sudbury area. The Metropolitan District Water Supply Commission thus

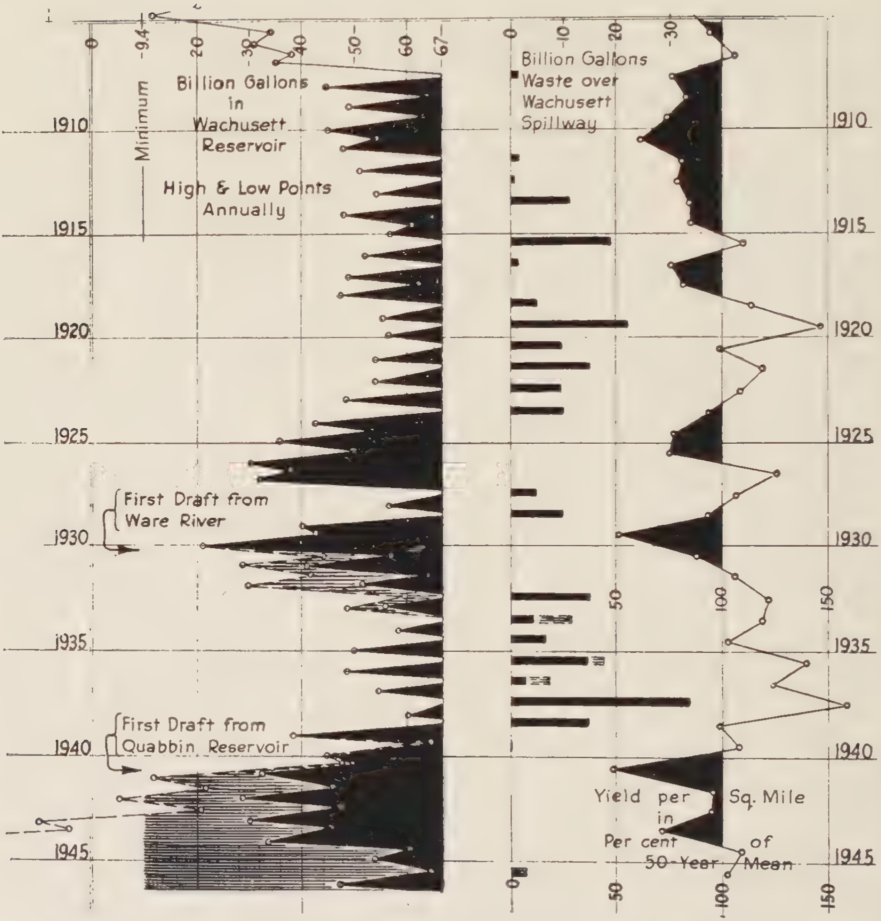


Fig. 1.—Fluctuations in Level of Wachusett Reservoir.

organized late in 1926, built in 1927 seven miles of pipe lines from three South Sudbury reservoirs. This emergency supply was not used to any great extent because the drought was brought to a sudden end by the so-called Vermont flood in the fall of 1927. The record of this and the subsequent sequence of dry and wet periods are clearly shown on the graph.

The next serious threat was the drought of 1930-31 and this too was short-lived. The new supply from the Ware was then available and the first diversion was made March 21, 1931. The growing inade-

### Principal Storage Reservoirs in Use by The Metropolitan Water District

| | *First Filled In* | *Drainage Area Now Directly Tributary Sq. Mi.* | *Max. Depth Feet* | *Area At Flow Line Acres* | *Capacity Between Bottom And Flow Line Bil. Gals.* | *Available For Draft To The District Bil. Gals.* | *Depth of Flashboard Control Below Flow Line Feet* | *Area Of Land Acquired Around The Reservoir Acres* | *High Water Flow Line B.C. Base* |
|---|---|---|---|---|---|---|---|---|---|
| Quabbin | 1946 | 186.0* | 150 | 24,700 | 412.3 | 417† | 2.0 | 56,200 | Elev. 530 |
| Wachusett | 1908 | 107.69* | 129 | 4,135 | 67.0 | 57.6‡ | 4.5 | 5,600 | Elev. 396.5 |
| Sudbury | 1898 | 22.28 | 65 | 1,292 | 7.25 | 6.8 | 1.0 | 1,450 | Elev. 260 |

*Also flood flows in excess of 1.36 cfs per sq. mi. are diverted from 96.8 sq. mi. of Ware River Watershed to Quabbin Reservoir up to a capacity of about 600 mgd and then to both Quabbin and Wachusett Reservoirs up to capacities of about 980 mgd to Quabbin and about 1,020 mgd to Wachusett simultaneously. Also, flood peaks from 9.35 sq. mi. of Worcester's Pine Hill-Kendall watershed occasionally spill into Wachusett Reservoir.

†Above the Quabbin Aqueduct Intake sill and including 15 Bil. Gals. estimated ground storage.

‡Above the lowest Intake sill. No estimate has been made of ground storage.

quacy of the Wachusett Reservoir to store enough of the flood flows to carry over a severe drought at that time is well illustrated on the graph. The spillway overflowed in both 1928 and 1929. Nearly 10 billion gallons were spilled in 1929. Nevertheless in February, 1931, the level had been pulled down about 46 feet. The graph clearly shows the subsequent occurrence of a series of wet years culminating in the unprecedented floods of 1936 and 1938. It also shows that even in spite of these floods, Wachusett Reservoir would have been practically empty five years ago if it had not been for the new supply.

## PWA PROJECTS

Ten or more years ago when Federal Aid for public works was getting into full swing, the Commission did not see any special benefit to the Commonwealth of Massachusetts in encouraging that policy. However, it became increasingly evident that there was no point in not joining the parade—in fact, very probably, a disadvantage in not doing so. As a result of an application for Federal assistance made in 1938, the Commission received one of the largest of the PWA 40 per cent grants. The application was centered on the construction of the pressure aqueduct and included not only numerous accessories connected with its operation, but also certain projects not connected in any way with the pressure aqueduct. Two applications were originally made to embrace all these items but as far as the grant was concerned, they were later incorporated into one account.

In addition to a number of minor contracts, the following major contracts were included in this PWA grant:

| *Contract No.* | *Description* |
|---|---|
| 61, 62, 63, 72 | Clearing the Quabbin Reservoir Site |
| 64 | Service Buildings along Quabbin Aqueduct |
| 66, 106 | Shallow Flowage Dams at Upper End of Quabbin Reservoir |
| 73, 89 | Weston Aqueduct Siphons |
| 74, 75, 76, 77, 78, 79, 81, 84, 85, 86 | The 18-Mile Pressure Aqueduct |
| 80, 96 | Norumbega Distributing Reservoir |
| 82, 107, 109, 124 | Scenic Road and Quabbin Hill Buildings |
| 83 | Spot Pond Bypass |
| 93 | Closing Gap in East Branch Baffle, Quabbin Reservoir |
| 94, 110 | Shaft 5 of City Tunnel |
| 99 | Enlargement of Fells Reservoir |
| 108 | Utility Wharves for Quabbin Reservoir |
| 111 | Winsor Dam Outlet Works Building |
| 116 | Quabbin Cemetery Building |

Several of these contracts had already been advertised, and bids for the work received, before the Federal grant was approved to include them. In each case the low bidder agreed to accept the work under a PWA contract without change in the bid price.

The total sum received as Federal aid, 40 per cent of the aggregate expenditures approved under the terms of the PWA grant, was $7,073,004.

### Obsolescence of Aqueducts

It is one thing to create a good water supply and another to maintain its purity. It is confidently hoped that effective steps can be taken to preserve and protect the Wachusett source. At least some of the old grade-line aqueducts passing through populated and polluting areas have already become obsolete and another will soon become so.

### Hultman Aqueduct

The construction of the new pressure aqueduct, recently named the Hultman Aqueduct, was authorized by the legislature as a result of a special joint report in 1937, by the Metropolitan District Water Supply Commission and the Department of Public Health, relative to improvements needed in the distribution system and to the prevention of pollution. This new aqueduct takes the water at the outlet chamber

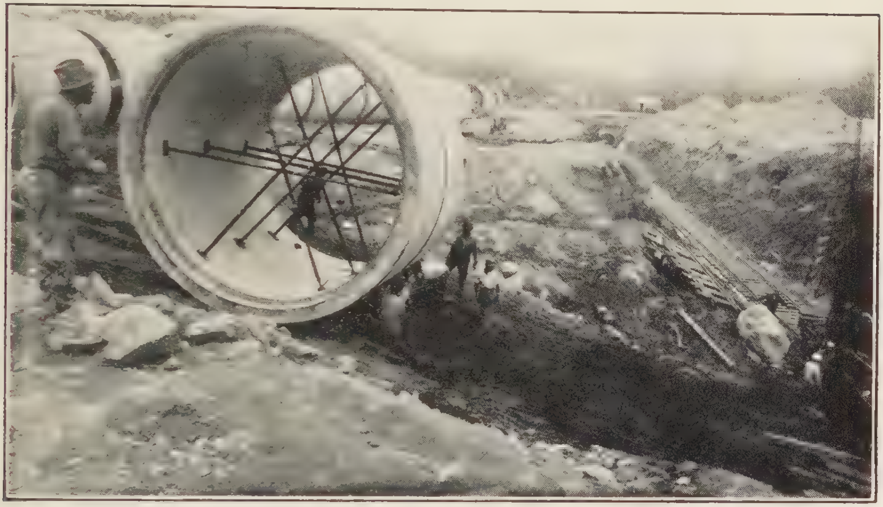
Governor Saltonstall and Party in the Hultman Aqueduct at its Dedication
October 23, 1940

of Wachusett Aqueduct and will ultimately deliver it to the District without exposure, except at the distributing reservoirs which equalize the rate of flow by taking care of the daily and weekly fluctuations in the consumption. The program in its larger phases not only includes the construction of the pressure aqueduct but also the elimination of sources of pollution connected with the existing works, the improvement of existing distributing reservoirs and pipe lines, and the construction of new distributing reservoirs.

The Wachusett Aqueduct had supplied the Sudbury Reservoir through an open channel which received a great deal of pollution locally. The upper 2400 feet of this channel was converted into a reservoir by raising the banks and diverting all local drainage through parallel channels to the downstream end. This reservoir serves as an equalizing basin between the grade-line Wachusett Aqueduct and the pressure Hultman Aqueduct. At its lower end a diversion spillway was constructed with head works which divert the water into the new aqueduct. Just below these head works, provision is made by which the aqueduct can in the future be extended, parallel to Wachusett Aqueduct, so as to take water directly from the outlet works at Wachusett Dam. This would not only materially increase its capacity but would also make it possible, if it should become necessary to do so, to construct on this extension a filtration plant capable of filtering the entire supply to the Metropolitan area.

The aqueduct bypasses Sudbury Reservoir by tunneling under it, and the gates which control the flow are housed in works at the top of the uptake shaft just below the old Sudbury Dam. At these control works, the flow can be divided by diverting into the head house of the old Weston Aqueduct at rates up to 100 million gallons daily, sufficient to meet all present and future needs of the District's low service supplied from the Weston distributing reservoir. In this way, Sudbury Reservoir itself which has supplied the Weston Aqueduct can be bypassed and held in reserve. The Hultman Aqueduct continues at the higher level to a new distributing reservoir in Weston, called Norumbega Reservoir. Its flow line is at Elevation 274.5 above Boston City Base or 74.5 feet higher than the Weston low service reservoir, but its level is subject to fluctuation on account of the fact that it rides as an equalizer on a pressure aqueduct instead of on a grade-line aqueduct.

The entire system must operate on flat gradients: 278.5, elevation



Placing 12′6″ Pre-Cast Pipe in the Hultman Aqueduct

of the spillway crest of the diversion dam at the aqueduct intake; 274.5, elevation of the spillway overflow at Norumbega Reservoir; 271, elevation of normal high water in the Fells distributing reservoir on the Northern High Service; and 264.5, elevation of the proposed flow line of a new distributing reservoir at the extreme limit of the Southern High Service in the Blue Hills reservation. It is because the existing works dictated this necessity of flat gradients that the aqueduct had to be constructed of such size, almost unprecedented in fact, for trench laid pre-cast concrete pipe.

The contract for the manufacture of the pipe and its delivery alongside the trench, although not the largest single contract executed by the Commission, was noteworthy both as to size and speed of execution. The manufacturer erected his plant in the first three months of 1939 on a site in Natick, which was ungraded and required starting from scratch. This involved not only a huge outdoor casting plant, but also a large steel plant and a concrete plant, all designed to turn out every day 24 complete pipe sections 11½′ diameter x 16′ long weighing up to 50 tons, requiring steam curing for 48 hours after the forms were removed and water-jet curing for an additional 12 days. In addition to meeting this schedule, the steel plant was also required to fabricate the cylinders and cages for still larger pipe, 12′6″ inside diameter x 12′ long, these to be hauled to the location of another concrete plant which had to be built in Southborough near the pipe trench to avoid the difficulty in transporting such huge finished pipe sections from the plant in Natick.

The delivery of pipe was started early in June, 1939. Although the contract called for completion in ten months, or before April 1, 1940, the pipe was practically all manufactured and 90 per cent delivered before the end of 1939. The laying of the pipe was divided into five other contracts. Two of these were performed by a contractor from the west coast with previous experience, but equally effective work was done by local contractors who had not previously handled pipe laying work of this magnitude. A most interesting and instructive paper on the design and construction of this aqueduct was prepared by Assistant Chief Engineer Stanley M. Dore, and published in the Journal of the N.E.W.W. Assoc. for September, 1941. That portion of the Hultman Aqueduct constructed to date includes the equalizing basin above the Intake and the new Norumbega Distributing Reservoir in Weston. The completed portion of the closed aqueduct extending from the Intake to the downtake shaft, No. 5, at the Charles River is 18 miles long and includes nearly five miles of tunnel under the Sudbury Reservoir.

The portion of the Hultman Aqueduct now under construction extending from the Charles River to Chestnut Hill is 5½ miles long all in deep rock tunnel. The completion of this City Tunnel, so called, is one of the most pressing requirements that lies ahead of us. It is urgently needed not only as a sanitary safeguard of the District's water supply, but also to supplement one of the weakest links in the distribution system so far as capacity is concerned. The legislature was concerned about this matter eleven years ago and in Chapter 48 of the Resolves of 1936, called for an investigation by the Commission and the Department of Public Health, already referred to above, relative to improving the distribution of water and preventing its pollution. The report of the joint board on this subject was published as House Document 262 of the year 1938, and recommended among other things "the immediate construction of . . . a section of pressure aqueduct about 5¾ miles long between a point near the Weston Aqueduct terminal chamber and a point near the Chestnut Hill Pumping Station." One of the reasons why this particular section was not built first was that the entire aqueduct construction was a PWA project. The length of time required to sink the shafts, excavate and line the tunnel and put it into service was much too great to meet the Federal requirements. Accordingly all efforts were concentrated on completing the 18-mile section west of the Charles River by dividing up the contract work, as already described. A satisfactory schedule was worked out for the rapid completion of the 3-mile tunnel section under the Sudbury Reservoir only by working from 4 closely spaced shafts, about one mile apart.

Then came the war which further delayed the work on the City Tunnel end of the line. The completion of this tunnel and the eliminatin of pumping at Chestnut Hill would correct admitted weaknesses in the Southern High Service delivery which supplied many important war industries, extending all the way from the Watertown Arsenal to the new shipyards across the Fore River from Quincy. On that account, the work received the endorsement of many highly placed Army and Navy officers and of other Federal agencies. In spite of this, the Commission was unsuccessful in obtaining permission to proceed with the work during the war on account of the fear that nothing could be accomplished in time to be of use in the war effort. The Commission was encouraged by the Federal authorities investigating the matter to study the possibilities of hastening the work, and surveys were made and plans drawn for doing the work from seven closely spaced shafts. The extra shaft sites, since abandoned, were on the Brae Burn golf course, the Newton Center playground and an area near the Hammond Pond Parkway. These efforts, however, were of no avail and in the meantime construction costs mounted and the consumption requirements of the District continued to tax the existing water supply lines.

At the present time, we are sinking two shafts, numbered 6 and 7. The tunnel will be constructed from the bottom of these shafts and also from the bottom of Shaft 5, which was sunk as a part of the first project.

Shaft 5 is located on the west bank of the Charles River at the easterly limit of the location on which it seemed practicable to use surface pipe, and where it was considered necessary to drop into deep hard rock tunnel under the closely built-up areas in Newton and Boston. The site so dictated could not be located at ledge outcrops and a caisson had to be sunk under compressed air to reach the surface of sound ledge, about 75 feet below the water level in the river. This is a multiple purpose, 3-way shaft. At the bottom of the shaft, about

355′ below the surface, there will be a chamber for tunnel unwatering pumps discharging into the Charles River above. This underground pumping station can unwater, for inspection or for any other emergency, not only the entire City Tunnel but also any future branch tunnel that may some day be required as the northerly leg of a loop distribution tunnel serving the Metropolitan area. Such a loop tunnel may never be built but provisions made for it are typical of the thought given to what is ahead, which we cannot afford to overlook in designing major works of this character. The central well in Shaft 5 is a dry well for access to the pump chamber. One of the side wells is the downtake to the City Tunnel, and the other to the future loop tunnel. The valves controlling the flow will be housed at the surface and make provision for connecting either or both of the downtakes to the surface conduit from Norumbega Reservoir, and also to a second duplicate and parallel conduit which some day may be constructed between Norumbega Reservoir and this downtake shaft, regardless of whether or not a corresponding duplication is required of the entire cut-and-cover line from the main control works at Sudbury Dam to Norumbega Reservoir, provision for which has been made.

Shaft 6 is now being sunk on land on Commonweath Avenue belonging to the Newton Cemetery Corporation. The cemetery now owns a large tract which could only be developed for burial purposes by filling a large swampy area extending for a considerable distance from the Avenue. The Commission has made an agreement with the cemetery which is mutually advantageous, and which will leave the area in a satisfactory condition for the development of a major extension of the useful burial area with another main entrance from Commonwealth Avenue supplementing the present area from Walnut Street. Under this agreement, the Commission will strip and save all available soil, will use the rock spoil excavated from the tunnel for filling to the contours desired by the Cemetery's landscape architect, and will replace the soil on the finished surface. Although the rock now being excavated from the shaft itself, and used to fill an area which will be used for access and not for graves, contains some large pieces, our experience in the excavation of tunnel bores is that the Contractor finds it advantageous to regulate his use of powder so that the spoil is relatively fine. In fact, the run of material in tunnel spoil along the Quabbin Aqueduct would make an excellent tennis court. In any event, the Contractor will be required to use special care in placing the top 5 feet, screening out all large stones. This shaft is mainly for construction purposes but in it will be installed an uptake pipe principally for the purpose of supplying the City of Newton. Anticipating the necessity of ultimately supplying the entire City from this point, the Commission will construct a foundation for a pumping station. A future lift at this point will be necessary since Newton's distributing reservoir is nearly 50 feet higher than Norumbega Reservoir. This station will be noiseless in operation, and designed to match in attractive appearance the buildings of the Cemetery Corporation.

Shaft 7 is now being sunk on a point of land jutting into the unused Lawrence Basin of Chestnut Hill Reservoir. This basin is separated by a dividing wall from the larger Bradley Basin, which is supplied from the low service mains and from Sudbury Aqueduct, and from which the pumps in the Chestnut Hill station now lift the water about 120 feet to supply the Southern High Service. They must continue to do so until the City Tunnel is completed. This shaft is a 3-way shaft principally to permit the installation at the surface of control gates which can isolate any one of the sections of distribution tunnel radiating from this central point. One branch will be extended northerly in the future to eliminate the present pumping at Spot Pond to the Northern High Service. This northerly extension together with the City Tunnel from Shaft 5 can, when and if the rate of consumption and other conditions in the District warrant it, be further extended to form the tunnel loop, previously referred to, and thus give the District an ideally safe 2-way system of gravity distribution. Although such a tunnel loop is something for the more remote future, the extension of the single deep rock bore to the north is a definite necessity that lies ahead for the Water District if it continues to grow. From this Shaft 7 another branch, included in the main City Tunnel contract soon to be advertised, will extend southeasterly to an uptake shaft, numbered 7A, in the rear of the Chestnut Hill pumping station and conveniently located for connection from the end of the branch to the discharge mains of the Southern High Service pumps thus adding about 15 or 20 feet to the hydraulic grade at that point. Provision will be made for a still further extension to the southeast in case expansion of the District in that direction makes it necessary.

### Principal Distributing Reservoirs of The Metropolitan Water District

|  | *First Filled in* | *Area Acres* | *Elev. Flow Line B.C. Base* | *Elev. Invert of Effluent Pipe B.C. Base* | *Available Capacity Mil. Gals.* | *Flow-through Type, or Riding as an Equalizer, or Normally Bypassed.* |
|---|---|---|---|---|---|---|
| *Low Service* (now about 85 mgd) |  |  |  |  |  |  |
| Weston | 1904 | 60.0 | 200 | 187.9 | 200 | Flow-through |
| Spot Pond | 1901 | 308.7 | 163 | 137.8 | 1,792 | Bypassed |
| *Hultman Aqueduct Service* (now about 12 mgd and in addition about 46 mgd required to be bled to Low Service to supplement that supplied through Weston Aqueduct, and about 12 mgd supplied to Spot Pond pumps for Northern High Service) |  |  |  |  |  |  |
| Norumbega Upper Basin | 1940 | 43.7 | 274.5 | 241 | 204.6* | Equalizer |
| *Southern High Service* (now about 61 mgd) |  |  |  |  |  |  |
| Bradlee Basin | 1868 | 85.0[x] | 134 | 109.8 | 523[x] | Equalizer** |
| Fisher Hill | 1887 | 3.14 | 251 | 230 | 15.5 | Equalizer |
| Waban Hill | 1877 | 2.8 | 264.5 | 246 | 13.5 | Equalizer† |
| *Northern High Service* (now about 12 mgd |  |  |  |  |  |  |
| Fells Reservoir | 1899 | 20.1 | 271 | 249.8 | 85.2 | Equalizer‡ |

PRINCIPAL DISTRIBUTING RESV. (Cont.)

*Other Principal Distributing Reservoirs on the Small Extra High Services* which will always Require Pumping (now totaling a little over 6 mgd, which is included in the above figures of consumption)

| | | | | | | |
|---|---|---|---|---|---|---|
| Bear Hill Res. | 1902 | 0.76 | 300 | 285 | 2.45 | Part of the Northern High Service |
| Arlington Res. | 1937 | 0.54 | 320 | 307.5 | 2.00 | Pumps supplied from Hultman Aqueduct Service |
| Arlington Standpipe | 1922 | 0.10 | 443 | 382 | 2.00 | Pumps supplied from Hultman Aqueduct Service |
| Turkey Hill Standpipe | 1945 | 1.10 | 443 | 380 | 2.00 | Pumps supplied from Hultman Aqueduct Service |
| Bellevue Standpipe | 1915 | 0.18 | 376 | 332 | 2.50 | Pumps supplied from Southern High Service |

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*The lower basin, not ordinarily used, when operating at 21.5 feet lower grade, adds 54.3 mil. gals. and 16.3 acres.

`The adjoining Lawrence Basin, not ordinarily used, could, after the completion of the City Tunnel, add about 147 mil. gals. and about 32 acres.

**Rides on the lines through which the Chesnut Hill pump sumps are supplied from the Low Service Mains and from Sudbury Aqueduct. The Chestnut Hill pumps normally supply the Southern High Service but can act as boosters to the Low Service.

†Normally rides at 8 or 10 feet higher elev. than, and gated off from, the principal Southern High Service mains.

‡Rides on the force main from Spot Pond pumps.

## FUTURE NEEDS OF THE DISTRIBUTION SYSTEM

Although the new watersheds that have been developed provide an ample supply, at the source, the capacity of the distribution system to deliver the water to the member municipalities in the Metropolitan area has, over the years, barely kept pace with the increase in consumption. In 1924, the Water Division of the Metropolitan District Commission began major reinforcements of the system by constructing additional supply mains from the outlet chamber of the Weston Aqueduct. During that year and the next, the Division issued $2,238,000 worth of long-term serial bonds for such construction and were able to reinforce the supply mains so that Spot Pond, at the north end of the District, could be served without resulting to low service pumping from Chestnut Hill Reservoir. Since that time no more serial bonds have been issued by the Metropolitan District Commission and its Water Division has been dependent upon annual appropriations by the legislature seldom over $400,000, and in some years less than $200,000 for the extension of the system of main supply lines. Appropriations generally do not equal the amounts budgeted by the Division for such necessary extensions and as a result the Division is continually handicapped in meeting the increasing needs.

The elimination of all pumping at Chestnut Hill is only one of the purposes of the new Hultman Aqueduct. Until the City Tunnel section of this aqueduct can be completed, the supply mains from the Weston Aqueduct are the main reliance of the District in distributing the supply to the different municipalities, since these supply mains are the only water routes into the Metropolitan area with the exception of the old Sudbury and Cochituate grade-line aqueducts. The Sudbury Aqueduct now has to bring in about 45 mgd because there is no other way of getting enough water to Chestnut Hill. This old grade-line aqueduct was found unsatisfactory from a sanitary standpoint 10 years ago by a joint board consisting of the Department of Public Health and the Metropolitan District Water Supply Commission, which recommended the immediate construction, at that time, of the 5¾-mile section of the Pressure Aqueduct, which we now call the City Tunnel, in order to eliminate the sources of pollution involved in the continued use of the old Sudbury Reservoir and Aqueduct. The Cochituate Aqueduct was also found unsatisfactory and the entire Cochituate source of supply has since been abandoned, and about to be turned over to the Department of Conservation for recreational use as provided in the current Senate Bill 517. The low service mains from the Weston Distributing Reservoir enter the District by three routes: by cast-iron mains in Commonwealth Avenue, by a steel main northerly through Arlington, and by a steel main along the Charles River to Brighton. These low service mains do not have sufficient capacity to carry the present consumption all the way from Weston Reservoir to Chelsea.

This situation is met at present by connecting the Arlington Line to the new Hultman pressure aqueduct and Norumbega Reservoir at 74 feet higher elevation than Weston Reservoir, thereby increasing the capacity of this line so that it can bleed about 7 mgd into the northerly end of the low service, where it is most effective. This timely increased pressure in the Arlington line is necessary to supply local requirements of another 7 mgd along the line, including 4 mgd to feed the Northern Extra High Service pumps in Arlington and Belmont, and this pressure is sufficient to supply directly without pumping another 4 mgd to what was formerly a part of the Northern High Service. This Arlington line continues to supply the Northern High Service pumps at Spot Pond but now delivers to the pump sump only about 12 mgd or ¾ as much as before the increased pressure in the Arlington line made it possible to supply an area in Medford and Somerville without pumping. Even under the higher head of Norumbega Reservoir, this Arlington line can deliver only about 30 mgd. It could not do much more without reducing the head on the Extra High Service pumps, particularly those in Arlington.

This situation is further relieved at present by connecting the Brighton line with the new pressure aqueduct and bleeding a controlled quantity of something like 38 mgd or more from this higher pressure into the low service in Brighton. These connections to the higher gradient necessarily decrease the quantity that can be delivered through the Weston Aqueduct since such delivery must now be confined to the capacity of the only remaining supply mains, in Commonwealth Avenue, only about 56 mgd. The principal advantage the completion of the City Tunnel will have in this respect is to allow bleeding from the Hultman Aqueduct to the low service by way of a proposed connection at Lake Street thus allowing the Brighton line to be reconnected to the Weston Aqueduct supply.

As the consumption increases and the loss of head in the low service distribution is consequently increased, it will be necessary either to drop the gradient somewhat at the Chelsea end or raise it at the Lake Street end which will reduce correspondingly the ability of the Weston Aqueduct to deliver the low service requirements. Another effect of increasing consumption will be that the Arlington line, which supplies the entire Northern High and Northern Extra High services as well as the municipalities enroute, will be taxed more and more, so that in order to maintain a satisfactory gradient at the Arlington pumping station, it can bleed less and less to the northerly end of the low service. These situations will hasten in a cumulative fashion the time when the distribution tunnel will have to be extended northerly from Shaft 7.

Such an extension of the distribution tunnel will make it possible to practically stop the disadvantageous bleeding into the low service at Lake Street and to supply the entire northern high service by gravity, thus taking this load off the Arlington line and allowing the low service to be again advantageously boosted at its northerly end, either by direct bleeding from the end of the extended tunnel itself in Malden, or from the Arlington line or both. In this way the low service gradients can be maintained more uniformly throughout the District and can be reduced to normal level in Brighton and vicinity, so that the draft through the Brighton and Commonwealth Avenue lines can be restored, and the flow in Weston Aqueduct increased to somewhat over 100 m.g.d. for the supply of the low service.

In this way a total consumption of somewhat in excess of 240 m.g.d. can probably be taken care of without the necessity for heavy additional expense in duplicating the pressure aqueduct line by means of the Y-branches and other facilities which were originally provided for future contingencies. It is reasonable to expect that the actual use of these provisions in the original design can be postponed for an indefinite period. Note that provision was also made in the original design for a less expensive method of meeting such a contingency, namely by inserting a booster pump on the connection between the Hultman Aqueduct and the Weston Aqueduct terminal chamber by means of which the Weston Aqueduct which has a capacity of 300 m.g.d. can bring in much more than it can deliver to the low service, the excess being pumped in the amounts desired to the Norumbega Reservoir level.

## Blue Hills Reservoir

One item of new construction which lies immediately ahead is the proposed distributing reservoir in the Blue Hills Reservation. Although this will come into its fullest use after the City Tunnel is completed, it is needed even before then to reinforce the Southern High Service and specific legislative approval to proceed with the construction has already been received.

Except for the small Southern Extra High Service which is pumped from the Hyde Park station, and of the Waban Hill Service which is not directly connected to the rest of the service, there is only one distributing reservoir riding on the Southern High Service. This is Fisher Hill Reservoir in Brookline. Of the total pumpage of approximately 60 million gallons daily, about 40 is taken off the main lines within two miles of the pumps and most of this goes to downtown Boston. Of the remaining 20 million gallons daily, about 2 supplies the Hyde Park pumping station and the remainder is supplied through connections all along the line to the extreme southeast end of the system where the City of Quincy takes a little over 6 million gallons daily. Fisher Hill Reservoir with an equalizing surface area of only 3.14 acres is the only distributing reservoir to take care of the daily and weekly fluctuations in the demand, and it is so far north that the service at the Quincy end suffers. We are making plans for a new reservoir in the Blue Hills Reservation and will locate the connecting line so that the needs in the most rapidly growing areas at the southeast end of the system can be best served.

The reservoir site chosen is on Chickatawbut Road just inside the Quincy line, locally known as Twin Brook Swamp just south of Fox Hill and Wampatuck Hill. The site is ideal, having an area of about 23 acres with steep side slopes and level bottom enabling the reservoir to be put into service at a level much below normal without decreasing its effectiveness. This feature would make it a very useful addition to the system even before the City Tunnel is completed and the gradient raised to that from Norumbega Reservoir. By pumping with the Chestnut Hill pumps against a 10-or 15-foot greater head and thereby bypassing Fisher Hill Reservoir, it should be possible to operate this proposed reservoir in the Blue Hills at about Elevation 250 although we would construct it with a maximum flow line at Elevation 264 expecting it to operate normally at least within 10 feet of this elevation, after the City Tunnel extension of Hultman Aqueduct from Norumbega Reservoir is completed. This reservoir would have a capacity at the flow line of a little over 160 million gallons.

## SEWERAGE PROJECTS

The construction program of the Commission includes five projects for extending the works of the North and South Metropolitan sewer systems:

Project 1—Sewage treatment plant on the South Metropolitan Trunk Sewer at Nut Island.

Project 2—Extension of North Metropolitan Relief Sewer to Deer Island including pumping station at East Boston, and design only of a sewage treatment plant at Deer Island.

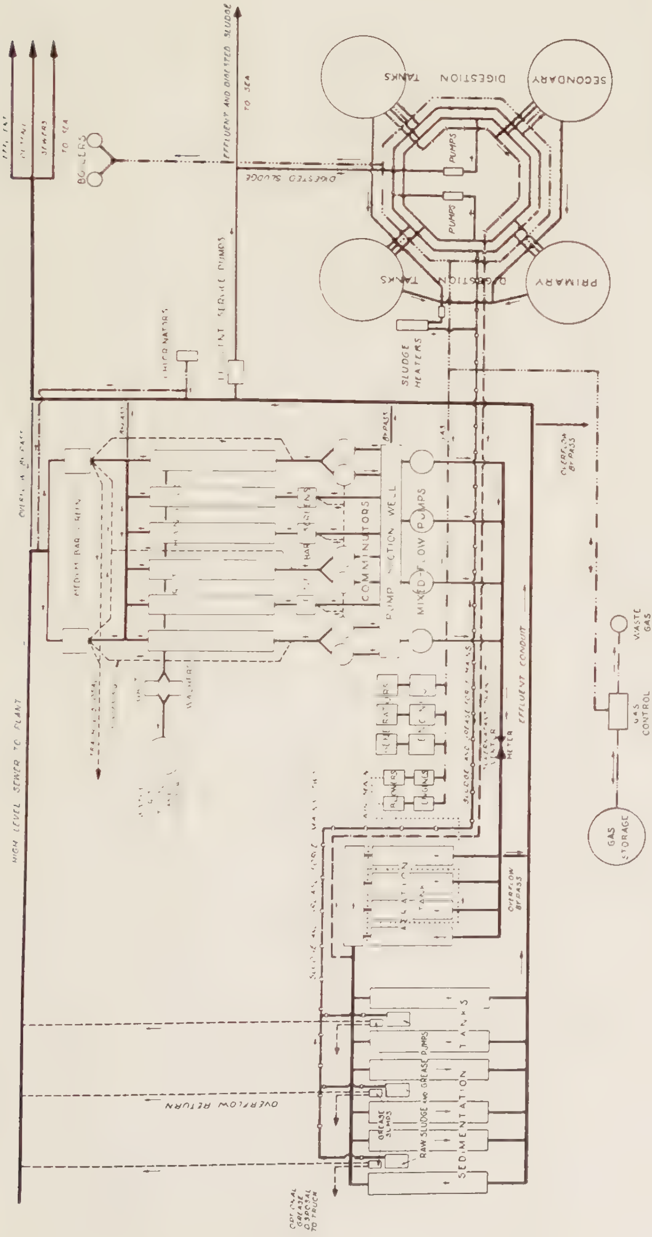
Project 3—Conduits and pumping station to relieve Alewife Brook Sewer, in the North Metropolitan system.

Project 4—Relief conduits and appurtenant works along the southerly side of the Charles River Basin.

Project 5—Relief conduits and appurtenant works along the northerly side of the Charles River Basin.

Unlike the water works extensions, these projects are dependent as to execution and progress on appropriations made by the legislature year by year. Project 2 is in the preliminary design stage. For Project 3, contracts are being prepared and the first will soon be advertised. Studies are in progress for Projects 4 and 5. Their design is related to that for Project 2 and a great deal of study is required to relate the projects properly to each other before reaching the stage of actual construction.

Project 1, the sewage treatment plant at Nut Island at the outlet of the South Metropolitan trunk sewer, is now under construction. At the present time, the trunk sewer has a capacity of 300 mgd and discharges raw sewage continuously through 60″ outlets approximately 6,000 feet from the shore. The existing plant consists of a single building where the larger solids are removed by manual cleaning of racks of the cage-elevator type. The treatment plant is designed for a rate of 112 mgd, as shown on the accompanying flow diagram. It consists first of two medium racks ahead of six parallel grit channels, three of which are followed by comminutors, two of 36″ diameter at the end of each channel, and each of the other three is followed by fine racks which discharge the rakings from high flows directly to the comminutors in the other low-flow channels. Four low-lift pumps then dis-



COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION (AS ENLARGED)
SOUTH METROPOLITAN SEWERAGE DISTRICT
NUT ISLAND SEWAGE TREATMENT WORKS
NUT ISLAND PLANT
FLOW DIAGRAM

charge through a Venturi meter of special design into five aeration channels, four parallel and one across their ends. These channels are designed to obtain flexibility in operation by cutting out one or more of the channels most remote from the pumps. The detention period is 20 minutes at the design rate and 32 minutes at the present normal dry summer weather flow of 70 mgd. The air capacity provided will give about 0.13 cubic foot per gallon at the design rate.

The influent conduit to the sedimentation tanks is specially designed so that no adjustments, at most only slight adjustments, will be needed to obtain a uniform distribution to the six tanks together with means for preventing excessive settlement of solids at the bottom of the conduit and for removing grease and scum at the top. The sedimentation tanks have a detention period of 88 minutes at the design rate and 141 minutes at the present normal dry summer weather rate, such as affects the recreation use of the harbor. The effluent conduit will discharge through the existing outfalls which will thus discharge the clarified effluent only instead of raw sewage as at present. One interesting feature of the new construction is the fact that a diffuser dome, to be pre-cast on the deck of a barge, will be lowered on prepared columns so as to cover the outlet and force a radial diffusion and a mixture of sea water with the effluent, as it rises through a coarse bar rack in the annular space as though between the petals of a huge daisy. This effluent will be chlorinated in summer.

It is expected that about 255,000 gallons of raw sludge, 95 per cent moisture, will be removed at the design rate, and about 215,000 gallons under present conditions. This will be pumped at three stations, one between each pair of sedimentation tanks. An interesting, and I believe unique, feature of the design is the collection of both the sludge on the bottom and the grease and scum on the top of the tank at the same point by means of long narrow collectors, one for each pair of tanks, which operate on the tank surface but separated from it by thin steel partitions extending only a short distance below the surface. The sludge and grease will be pumped to four digestion tanks 110 feet in diameter each having a working capacity of 2,300,000 gallons. Two tanks with fixed covers are operated as primary digestion tanks, and two with floating covers as secondary digestion tanks. It is expected that the daily gas production will be about 675,000 cubic feet at the design rate, and about 525,000 under present conditions. The contents of the tanks will be heated by continuous circulation through outside sludge heaters, the heat being supplied by water circulated from the gas engine jackets.

The digested-sludge disposal line will be a 12″ pipe laid across the harbor to Long Island, thence along the shore of Long Island and out into the deep water in President Roads. At the southerly end of Long Island, provision has been made for receiving similar digested sludge from a plant which the City of Boston is planning to construct to treat the sewage of the Boston Main Drainage System, now discharged at the Moon Island outlet on the outgoing tide without treatment. One feature of the work which is interesting, and also, I believe, unique so far as the planned regular scheduling of the operation is concerned, is that all pipes carrying sludge will be kept clean by go-devils, so called.

The power plant will consist of one 600 KW gas-engine generator unit, two 600 KW dual-fuel-engine generator units and two 210 HP dual-fuel engines directly connected to blowers of 5,000 cfm capacity. The gas engine will operate solely on digester gas. The dual-fuel engines will run on digester gas or oil or both. The plant will be independent of outside power and light. Each of the four main low-lift pumps of the mixed-flow type will each be motor-driven through a planetary-gear speed reduction with magnetic drive for speed variation. One unit is a spare and each unit is capable of delivering 83 mgd against a head of 10.3 feet.

A more complete description of the treatment plant is contained in articles by the writer in the Civil Engineering magazine of the American Society of Civil Engineers in the issues for June and July, 1946.

## CONSTRUCTION COSTS

For all the construction work done to date including commitments on account of all contracts executed, but none which have not yet reached the stage of actual execution, the Commission has spent the aggregate sum of $71,254,899.

If this sum is spread over the entire life of the organization since work first started, including the relatively unproductive war years, it averages roughly $10,000 a day.

The work has included 88 major contracts and over 50 minor ones. The engineering organization, exclusive of laborers, has numbered nearly 400 at its peak and now numbers a little over 160. The total

METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

*Net Construction Costs (including contract commitments to March 1, 1947)*

| *Contract No.* | *Description* | *Contractor* | *Date* | *Cost* |
|---|---|---|---|---|
| SOUTHERN SUDBURY EMERGENCY SUPPLY: | | | | |
| 5 | Cordaville Pipe Line 30" Conc. 9,222 feet | Lock Joint Pipe Co. | Apr. 22, 1927 | $ 83,763. |
| 7 | Hopkinton " " 30" C.I. 6,978 feet | Cenedella & Co. | May 7, 1927 | 134,366. |
| 11 | Ashland " " 24" C.I. 14,362 feet | Antonio Mogavero | June 8, 1927 | 130,146. |
| 13 | Whitehall " " 20" C.I. 6,750 feet | Portland Contr. Co., Inc. | July 20, 1927 | 60,603. |
| 16 | Whitehall Open Channel | Sanders Eng. Co. | Sept. 28, 1927 | 32,695. |
| 6, 15, | Minor Contracts | | | 17,655. |
| Other Construction by Force Acct., Purchase of Materials, Equipment, etc. | | | | 11,667. |
| | | | | $470,895. |
| QUABBIN AQUEDUCT: | | | | |
| 1 | Borings | Pennsylvania Drilling Co. | Nov. 15, 1926 | $ 18,642. |
| 4 | One Shaft & 1,367 ft. of Tunnel Excavation | Jas. J. Coughlan & Sons, Inc | Mar. 30, 1927 | 290,582. |
| 8 | Two Shafts & 3,062 ft. of Tunnel Excavation | Jas. J. Coughlan & Sons, Inc. | Jun. 2, 1927 | 456,784. |
| 10 | Transmission Line for East Portion | New England Power Co. | Apr. 27, 1927 | 119,547. |
| 12 | Three Shafts & 3,180 ft. of Tunnel Excavation | Dravo Contracting Co. | Jun. 1, 1927 | 632,727. |
| 14) | Two Shafts & 14.19 miles of Tunnel, incl. | | | |
| 17) | Lining Previous Excavation | West Construction Co. | Apr. 30, 1928 | 7,642,881. |
| 19 | Ware Intake Substructure and Dam | J. W. Bishop Co. | Jul. 23, 1929 | 285,580. |
| 20 | Five Shafts & 10.38 miles of Tunnel | Wenzel & Henock Constr. Co. | Apr. 23, 1931 | 4,809,853. |
| 24 | Superstructure Ware Intake Building | Munroe & Westcott, Inc. | Jul. 23, 1930 | 70,114. |
| 25 | Superstructure Wachusett Outlet Building | Munroe & Westcott, Inc. | Jul. 23, 1930 | 62,329. |
| 47 | Buildings at Quabbin Intake | Vincent Caira | May 4, 1936 | 35,745. |
| 64 | Service Bldgs. at Ware Intake & Wachusett Outlet | Platt Contr. Co., Inc. | Oct. 25, 1938 | 82,512. |
| 152A | 5,000 H.P. Turbine for Oakdale Station | S. Morgan Smith Co. | Feb. 6, 1947 | 98,500.* |
| 152BCDF | 4375 kva Generator, Switchgear etc. | General Electric Co. | Feb. 13, 1947 | 115,069.* |

*Basis of award, contract not yet complete

METROPOLITAN DISTRICT WATER SUPPLY COMM. (Cont.)

| Contract No. | Description | Contractor | Date | Cost |
|---|---|---|---|---|
| QUABBIN AQUEDUCT (Cont.): | | | | |
| 152G | 84" Penstock Valve | Chapman Valve Mfg. Co. | Feb. 13, 1947 | $ 31,850.* |
| 18, 22, 26, 28, 29, 31, 33, 53, 65, 67, 98, 105 (part), 112, 152E*, Minor Contracts | | | | 121,548. |
| Other Construction by Force Acct., Purchase of Materials, Equipment, etc. | | | | 232,247. |
| | | | | $15,106,510. |
| QUABBIN RESERVOIR | | | | |
| (a) | *Winsor Dam and Quabbin Dike* | | | |
| 2 | Borings | Sprague & Henwood, Inc. | Nov. 12, 1926 | $ 26,886. |
| 23 | Borings | Sprague & Henwood, Inc. | Nov. 13, 1929 | 59,044. |
| 30 | Stream Control Tunnel, Winsor Dam | Northern States Contr. Co. | Aug. 1, 1931 | 544,611. |
| 32 | Exploratory Caissons at Dam & Dike | Dravo Contracting Co. | Sep. 16, 1931 | 162,838. |
| 36 | Caisson Core Wall, Quabbin Dike | West Construction Co. | Dec. 28, 1932 | 1,151,602. |
| 38 | Caisson Core Wall, Winsor Dam | The Two Companies, Inc. | May 15, 1935 | 1,606,630. |
| 50 | Quabbin Dike Embankment | The Arthur A. Johnson Corp. | Dec. 5, 1934 | 1,402,752. |
| 52 | Winsor Dam Embankment | Benj. Foster Co. | Aug. 24, 1936 | 2,439,728. |
| 111 | Winsor Dam Outlet Works Superstructure | Chandler Constr. Co., Inc. | Oct. 18, 1940 | 48,060. |
| 149A | 1700 H.P. Turbine | S. Morgan Smith Co. | Jun. 25, 1945 | 27,953.* |
| 149B | 1500 kva Generator | Elec. Machinery Mfg. Co. | Jul. 16, 1945 | 17,192.* |
| 150 | Installation Winsor Dam Power Plant | Berke Moore Co. | Mar. 27, 1946 | 39,198.* |
| 35, 37, 45, 121 (part), 122, 149C-F*, Minor Contracts | | | | 58,479. |
| Other Construction by Force Acct., Purchase of Materials, Equipment, etc. | | | | 98,651. |
| | | | | $7,683,624. |
| (b) | *Other Reservoir Construction* | | | |
| 49 | Diversion Channels from Ware Outlet Shaft | Cenedella & Co. | Oct. 2, 1935 | $ 87,929. |
| 51 | East Branch Baffle, Main Portion | Franklin A. Snow Co. | Jun. 23, 1936 | 198,407. |
| 56 | Administration Buildings | Rich Bros. Constr. Co., Inc. | July 28, 1937 | 382,118. |
| 60 | Access road to Quabbin Aque. Intake | Middlesex Constr. Co. | Jan. 6, 1938 | 81,625. |
| 61 | Clearing West Branch, 5200 acres | Coleman Bros. Corp. | Oct.20, 1938 | 273,204. |

*Basis of award, contract not yet complete

Metropolitan District Water Supply Comm. (Cont.)

| *Contract No.* | *Description* | *Contractor* | *Date* | *Cost* |
|---|---|---|---|---|
| Quabbin Resv. (b) | *Other Reservoir Construction* (cont.) | | | |
| 62 | Clearing Lower Mid. & E. Branch, 6500 acres | Coleman Bros. Corp. | Oct.20, 1938 | 351,449. |
| 63 | Clearing Middle Branch, 4200 acres | Coleman Bros. Corp. | Oct. 20, 1938 | 211,846. |
| 66 | 2 Shallow Flowage Dams & Clearing 702 acres | C & R Constr. Co. | Oct. 25, 1938 | 188,966 |
| 72 | Clearing Upper Mid. & E. Branch, 8200 acres | C & R Constr. Co. | Oct. 25, 1938 | 476,375. |
| 82 | 4.3 Miles Quabbin Hill Scenic Road | G. Rotondi & Sons | Mar. 9, 1939 | 228,551. |
| 93 | Completion of East Branch Baffle | J. J. Callahan | Oct. 27, 1939 | 25,102. |
| 106 | Access Roads | A. R. Montuori & Co. | Jun. 5, 1940 | 27,433. |
| 107 | Quabbin Hill Buildings | H. P. Cummings Constr. Co. | Dec. 2, 1940 | 72,477. |
| 108 | Utility Wharves | J. J. Callahan | Sep. 27, 1940 | 18,528. |
| 109 | Radio System of Intercommunication | Kenworthy & Taylor, Inc. | Oct. 30, 1940 | 20,989. |
| 124 | Transmission Line to Quabbin Hill | George W. Ellis Co. | Feb. 3, 1941 | 15,142. |
| 3, 9, 59, 102, 103, 105(part), 118, 119, 120, 123(part), 125, | Minor Contracts | | | 44,827. |
| Other Construction by Force Acct., (incl. Preliminary Clearing project), Pur. of mat., equip., etc. | | | | 2,156,359. |
| | | | | $4,861,327. |
| (c) | *Relocation of Highways, Cemeteries and Public Utilities* | | | |
| 21 | 5.2 miles Ware-Belchertown Highway | Lane Construction Co. | Jul. 20, 1931 | $ 225,707. |
| 40 | Trans. Line Reloc. 8.5 mi. 66,000 V. incl. damages | New England Power Co. | Jun. 20, 1933 | 154,790. |
| 41 | 9.1 miles Belchertown-Pelham Highway | Carlo Bianchi Co., Inc. | Jul. 20, 1933 | 248,578. |
| 43 | 7.6 miles Pelham-New Salem Hghway | V. Barletta Co. | Aug. 25, 1933 | 387,605. |
| 44 | 4.1 miles New Salem Highway | John Iafolla Constr. Co. | Nov. 15, 1933 | 199,940. |
| 54 | 1.8 miles Dana-Petersham Highway | Carlo Bianchi & Co., Inc. | May 22, 1936 | 63,841. |
| 55 | 4.2 miles Petersham-New Salem Highway | Arute Bros. Inc. | Jun. 23, 1936 | 239,157. |
| 57 | 3.8 miles Petersham-New Salem Highway | John Iafolla Constr. Co. | Sep. 1, 1936 | 168,823. |
| 116 | Cemetery Building | Chandler Constr. Co., Inc. | Oct. 25, 1940 | 10,871. |
| 34, 88 | Minor Contracts | | | 16,205. |
| All other expense of Relocation of Cemeteries by Force Acct. etc. | | | | 554,449. |
| | | | | $2,269,966. |

METROPOLITAN DISTRICT WATER SUPPLY COMM (Cont.)

| *Contract No.* | *Description* | *Contractor* | *Date* | *Cost* |
|---|---|---|---|---|
| WATERSHED PROTECTION: | | | | |
| 39 | Rutland-Holden Trunk Sewer, 50,209 ft. | Jas. J. Coughlan & Sons, Inc. | Jul. 11, 1933 | $ 238,709. |
| 70 | Rutland Sewer System by Force Acct., except some W.P.A. Labor | | | 136,058. |
| 71 | Holden ” ” ” ” ” ” ” ” ” | | | 153,742. |
| 27 | Minor Contract | | | 4,396. |
| Other Construction by Force Acct. (incl. Reforestation), Purchase of Materials, Equipment, etc. | | | | 928,760. |
| | | | | $1,461,665. |
| HULTMAN AQUEDUCT: | | | | |
| 74 | Four Shafts & 3.0 miles of Tunnel | West Constr. Co. | Dec. 30, 1938 | $ 2,933,832. |
| 75 | Laying 12′6″ Pipe 9,665 feet | B. A. Gardetto, Inc. | Mar. 10, 1939 | 521,807. |
| 76 | Borings | Sprague & Henwood, Inc. | Oct. 20, 1938 | 22,219. |
| 77 | Laying 11′6″ Pipe 16,565 feet | B. A. Gardetto, Inc. | May 3, 1939 | 496,597. |
| 78 | Laying 11′6″ Pipe 17,800 feet | Am. Conc. & Steel Pipe Co. | Mar. 20, 1939 | 551,629. |
| 79 | Laying 11′6″ Pipe 18,000 feet | Am. Conc. & Steel Pipe Co. | Mar. 20, 1939 | 522,335. |
| 80 | Norumbega Distributing Reservoir & Gatehouse | Carlo Bianchi & Co., Inc. | Jun. 15, 1939 | 574,184. |
| 81 | Laying 11′6″ Pipe 15,270 ft. & 7′ Pipe 2,305 ft. | M. F. Gaddis, Inc. | Apr. 26, 1939 | 615,155. |
| 84 | Shaft Headhouse and Control Works | John F. Griffin | Sep. 18, 1940 | 100,673. |
| 85 | Mfg. & Del. of Conc. Pipe 9,561′ of 12′6″, 67,721′ of 11′6″, 2,268′ of 7′ | Lock Joint Pipe Co. | Dec. 28, 1938 | 4,198,409. |
| 86 | Miscellaneous Valves | Chapman Valve Mfg. Co. | Jun. 15, 1939 | 81,086. |
| 94 | Caisson for Charles River Shaft | John MacDonald Constr. Co. | Feb. 20, 1940 | 190,396. |
| 96 | Chlorinating Plant at Norumbega Reservoir | Chandler Constr. Co. Inc. | Apr. 5, 1940 | 54,795. |
| 110 | Completion of Charles River Shaft | C & R Constr. Co. | Sep. 13, 1940 | 205,195. |
| 117 | Two Shafts for City Tunnel | Marinucci Bros. & Co. | Nov. 25, 1946 | 522,529.* |
| 87, 90 (part), 91, 92 (part), 95 (part), 101, 104 (part), 105 (part), 113, 114 121 (part), 123 (part), 127, 128, 129, 130, 134 (part) | | Minor Contracts | | 156,253. |
| Other Construction by Force Acct., Purchase of Materials, Equipment, etc. | | | | 68,726. |
| | | | | $11,815,820. |

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*Basis of award, contract not yet complete

METROPOLITAN DISTRICT WATER SUPPLY COMM. (Cont.)

| *Contract No.* | *Description* | *Contractor* | *Date* | *Cost* |
|---|---|---|---|---|
| MISC. ADDITIONS TO THE WATER WORKS SYSTEM: | | | | |
| 73 | Additional Weston Aque. Siphons 4,787 ft. 8′6″ Conc. | Leo Butler Co. | Nov. 17, 1938 | $ 261,468. |
| 83 | Spot Pond Bypass 60″ Conc. Pipe 4,357 ft. | S. Rontondi & Sons Co. | Aug. 29, 1939 | 141,894. |
| 89 | Mortar Lining of Old Weston Aque. Siphons | Marinucci Bros. & Co. | Nov. 6, 1939 | 42,941. |
| 99 | Enlargement of Fells Reservoir | Middlesex Constr. Co. | Jan. 9, 1940 | 145,116. |
| 133 | Assabet Siphon on Wachusett Aqueduct | Berke Moore Co., Inc. | Aug. 28, 1946 | 197,758.* |
| 83A, 90 (part), 92 (part), 95 (part), 97, 100, 104 (part), 134 (part) | Minor Contracts | | | 55,046. |
| Other Construction by Force Acct., Purchase of Materials, Equipment, etc. | | | | 1,520. |
| | | | | $ 845,743. |
| NUT ISLAND SEWAGE TREATMENT PLANT: | | | | |
| 136 | Excavation & Filling to Prepare the Site | V. Barletta Co. | Oct. 18, 1945 | $ 478,814.* |
| 137 | Concrete Tanks, Conduits, Foundations | V. Barletta Co. | Aug. 27, 1946 | 1,179,763.* |
| 138 | Soundings for Sludge Disposal Line | Greenland Drilling Co. | Nov. 28, 1945 | 15,489. |
| 139 | Sludge Disposal Line—12″ Cast Iron 21,300′ | Bay State Dredg. & Contr. Co. | Nov. 4, 1946 | 575,724.* |
| 141 | 3 Engine Driven Generators, 4 Main Pump Units and 2 Blower Units | Worthington Pump & Machinery Corp. | May 31, 1946 | 330,374.* |
| 142A-H | Grit Washers & Grit Sludge & Scum Collectors | Jeffrey Mfg. Co. | Mar. 26, 1946 | 137,927.* |
| 142 I | 6 Comminutors | Chicago Pump Co. | Mar. 19, 1946 | 40,244.* |
| 144 C | Diffuser Tube Aeration System | Chicago Pump Co. | Sep. 16, 1946 | 33,954.* |
| 144 E-F | 2 Digestion Tank Covers & Supernatant Selectors | Pacific Flush Tank Co. | Oct. 3, 1946 | 55,088.* |
| 144 G | Chlorinating Equipment | Wallace & Tiernan Co., Inc. | Sep. 23, 1946 | 48,927.* |
| 144 A, B, D, 147 | Minor Contracts | | | 40,466. |
| Other Construction by Force Acct., Purchase of Materials, Equipment, etc. | | | | 173. |
| | | | | $ 2,936,943. |

*Basis of award, contract not yet complete

### METROPOLITAN DISTRICT WATER SUPPLY COMM. (Cont.)

| | |
|---|---|
| *In Addition to Net Construction Costs (to March 1, 1947)* | |
| REAL ESTATE: | |
| Southern Sudbury Emergency Supply | $ 30,553. |
| Quabbin Aqueduct | 209,687. |
| Quabbin Reservoir incl. B. & A. RR. Settlement | 9,531,533. |
| Ware and Wachusett Watersheds | 1,581,138. |
| Hultman Aqueduct | 576,290. |
| Misc. Additions to Water Works System | 689. |
| Nut Island Sewage Treatment Plant | 1,232. |
| | $11,931,122. |
| DIVERSION DAMAGES: | |
| Southern Sudbury Emergency Supply | |
| Quabbin Reservoir | $ 50,753. |
| Ware Supply | 1,429,558. |
| Swift Supply | 1,899,687. |
| | $ 3,379,998. |
| DEFENSE OF BREACH OF CONTRACT SUITS: | |
| Quabbin Reservoir | $ 22,317. |
| Winsor Dam & Quabbin Dike | 77,384. |
| | $ 99,701. |
| LIQUIDATION OF TOWNS: | |
| Dana, Enfield, Greenwich, Prescott | $ 111,259. |
| FEE FOR CONNECTION OF RUTLAND-HOLDEN TRUNK SEWER WITH WORCESTER SYSTEM | $ 325,000. |
| SPECIAL INVESTIGATIONS: | |
| Chapter 66 Resolves of 1931 | $ 1,995. |
| " 18 " " 1936 | 12,513. |
| " 48 " " 1936 (incl. Boring Contract No. 58) | 135,102. |
| " 59 " " 1945 | 1,659. |
| " 83 " " 1945 | 875. |
| | $ 152,144. |

Metropolitan District Water Supply Comm. (Cont.)

| | |
|---|---|
| Field Engineering 1926 to Date (incl. all necessary maintenance until separate maintenance appropriations were authorized commencing in 1943): | |
| Southern Sudbury Emergency Supply | $ 44,235. |
| Quabbin Aqueduct | 912,556. |
| Winsor Dam—Quabbin Dike | 751,263. |
| Other Quabbin Reservoir (incl. surveys of 80,961 acres) | 1,342,984. |
| Hultman Aqueduct, includes also some headquarters engineering (PWA account) | 1,190,157. |
| Misc. Additions to Water Works System | 57,424. |
| Nut Island Sewage Treatment Plant | 189,493. |
| Surveys for Other Sewerage Projects not yet under Construction | 30,432. |
| | $4,518,544. |
| Headquarters, Engineering, Design, and Administration Overhead: | |
| Southern Sudbury Emergency Supply | $ 42,098. |
| Quabbin Aqueduct | 722,276. |
| Watershed Protection | 60,278. |
| Winsor Dam and Quabbin Dike | 464,614. |
| Other Quabbin Reservoir | 1,281,226. |
| Hultman Aqueduct (incl. preparation of important contracts not yet executed) | 283,371. |
| Misc. Additions to Water Works System | 27,257. |
| Undistributed for present fiscal year July 1, 1946 to date | 54,544. |
| Nut Island Sewage Treatment Plant, (incl. preparation of important contracts not yet executed) | 336,990. |
| Other Sewerage Projects (incl. preparation of important contracts not yet executed) | 11,984. |
| | $3,284,638. |

MET. DIST. WATER SUPPLY COMM.—SUMMARY OF EXPENDITURES AND CONTRACT COMMITMENTS TO MARCH 1, 1947

| | | |
|---|---|---|
| SOUTHERN SUDBURY EMERGENCY SUPPLY: | | |
| 5 Major contracts and other net construction cost | $ 470.895. | |
| Real Estate | 30,553. | |
| Diversion Damages | 50,753. | |
| Field Engineering | 44,235. | |
| Headquarters Engineering, design and administrative overhead | 42,098 | |
| | | $ 638,534. |
| QUABBIN AQUEDUCT: | | |
| 15 Major contracts and other net construction cost | $15,106,510. | |
| Real Estate | 209,687. | |
| Field Engineering, including maintenance until 1943 | 912,556. | |
| Headquarters Engineering, design and administrative overhead | 722,276. | |
| | | $16,951,029. |
| QUABBIN RESERVOIR: | | |
| 12 Major contracts, etc. for Winsor Dam and Quabbin | $ 7,683,624. | |
| 16 Major contracts, etc. for Reservoir construction | 4,861,327. | |
| 9 Major contracts, etc. for Relocations | 2,269,966. | |
| 4 Major contracts, etc. for Protection of all watersheds | 1,461,665. | |
| Real Estate, including all watersheds | 11,112,671. | |
| Diversion Damages | 3,329,245. | |
| Defense of breach of contract suits, liquidation of towns, fee for Worcester connection | 535,960. | |
| Field Engineering, including maintenance until 1943, and all surveys | 2,094,247. | |
| Headquarters Engineering, design and administrative overhead | 1,806,118. | |
| | | $35,154,823. |

### MET. DIST. WATER SUPPLY COMM.—SUMMARY (Cont.)

| | | |
|---|---|---|
| HULTMAN AQUEDUCT: | | |
| 15 Major contracts and other net construction cost | $11,815,820. | |
| Real Estate | 576,290. | |
| All Engineering, design and overhead including maintenance until 1943, also preparation of important contracts not yet executed | 1,473,528. | |
| | | $13,865,638. |
| MISC. ADDITIONS TO THE WATER WORKS SYSTEM: | | |
| 5 Major contracts and other net construction cost | $ 845,743. | |
| Real Estate | 689. | |
| Field Engineering | 57,424. | |
| Headquarters Engineering, design and administrative overhead | 27,257. | |
| | | $ 931,113. |
| SEWERAGE PROJECTS: | | |
| 11 Major contracts and other net construction cost | $ 2,936,943. | |
| Real Estate | 1,232. | |
| Field Engineering | 219,925. | |
| Headquarters Engineering, design and overhead including preparation for new contracts | 348,974. | 3,507,074. |
| SPECIAL INVESTIGATIONS | | 152,144. |
| UNDISTRIBUTED OVERHEAD IN THE CURRENT FISCAL YEAR | | 54,544. |
| | | $71,254,899. |

number of individuals that have been connected with the organization during its lifetime is much greater than these figures would indicate. It sent 128 into the armed services. It also supplied from its roster key personnel for a great many of the service and non-service activities which sprang up throughout the nation to feed the war effort. The organization takes a justifiable pride in its record.

## Relations with Contractors

One important feature of the Commission's construction program is that it has vigorously defended its contractual rights whenever they have been assailed by court action. It is a common misapprehension that laws are made by the legislature. It would be nearer the truth to say that the legislature enacts the laws, but it is only when their interpretation is questioned and taken before the highest legal tribunal for interpretation that the law is actually established. By carrying its cases to the Supreme Court of the Commonwealth the Commission has been instrumental in establishing a considerable body of construction contract law.

One of the Commission's contract suits had to do with the question of adequacy and correctness of information given on plans or, whether the contract really means what it says when it states that there is no guarantee as to the accuracy of the information given or as to interpretations of it. In this connection it has always been our policy to relieve the contractor of all the risks that we possibly can, and we believe it is a good investment to spend money liberally for sub-surface investigations. In the case referred to, we were not even satisfied with the many borings and hand-made test pits which were put down to locate suitable borrow pits but in addition to these, we let a preliminary contract under which we made four sizeable power-shovel cuts into the hillsides and exposed the materials to the view of prospective bidders. There is no question but what bidders lean heavily on the information and interpretations which the engineer gives them. It is equally clear that it is part of the contractor's business to evaluate the risks. No matter how forehanded the engineer may be in the matter of borings, he cannot warrant or guarantee any and all interpretations of the data and the reason for excluding all such guarantees in the contract documents need hardly be discussed further. In this case the contractor in preparing his bid had discussed the Commission's preliminary work in great detail with a number of the engineers and very properly attempted to get all the expert opinion he could. Subsequently he found the digging much harder than he anticipated. The number of boulders encountered was large as was indicated to be the case by the boring plans, and the boulders were imbedded over large areas in glacial till. He claimed in his petition that there was a breach of warranty, stressing the fact that we did not describe certain glacial till as hardpan, in spite of the language of the contract which stated that the accuracy of the boring plans or any interpretations of them were not guaranteed to be correct and that each bidder must form his own opinion of the character of the materials to be excavated and make his own interpretations of the borings, test pits and shovel cuts and must satisfy himself by his own investigations and research.

The following excerpts have been selected from the decision of the Supreme Court in this important case: "Where, as here, a written contract shows on its face that it comprises the entire agreement and was intended to be a complete and final statement of the whole transaction, then express warranties other than those contained in the contract cannot be added by extrinsic evidence." The judge who heard the findings of the Auditor in this case had found that upon all the evidence "the boring plans were true and accurate portrayals of the borrow areas and were drawn according to well recognized and approved engineering practice", also "that there was no breach of any express or implied warranty, and that neither the commission nor any of its representatives made any false representation or concealed any information whereby the petitioner was deceived or defrauded", also "that a careful examination of the plans furnished the petitioner or a careful examination of the shovel cuts and the surrounding territory by an experienced engineer would have revealed the fact that the overburden of the borrow area was a glacial till containing at least ten per cent of boulders, some of which were eight to ten feet in diameter"; and also that "It would almost seem to be common knowledge that the excavation of glacial till of the character revealed by the shovel cuts in this area would not be easy". In supporting these findings, the court decided that "If the judge believed that an experienced contractor who had examined the shovel cuts would not be misled by these plans, we cannot say that he committed any error of law in reaching that conclusion", and that the general finding for the Commission was "supported on any rational view of the evidence together with the permissible inferences. The petitioner in the absence of fraud had no enforceable claim under either aspect of its petition."

This decision was similar to that in the case of another of the Commission's contract suits which was not so clear cut because it involved in addition to the main item several minor matters which the Commission did not originally contest and which it was in fact willing to agree upon and include in the final estimate. However, the contractor refused to accept the final estimate and instead included all these minor items in its suit. The main item had to do with the location of a quarry site. The contractor claimed that he relied on verbal statements of the Commission's engineers as to the availability of a favorable site which eventually he was unable to obtain. The decision of the court was somewhat similar to that in the case first mentioned, and the contractor was held responsible for determining all such facts himself.

Another of the Commission's contract suits had to do with the question of the engineer's responsibility, again as to whether the contract really means what it says when it states in effect by various detailed, explicit and emphatic wordings that the work shall be performed according to the orders and to the satisfaction of the engineer, the reason for these provisions being that the contract was for a hydraulic fill dam the safety and usefulness of which was dependent upon the constant supervision of the details of the work by skilled engineers who were given considerable leeway under the contract in the selection or rejection of borrow pit materials, and in the modification of the dimensions and characteristics of the resulting core of the dam as the work progressed.

The following excerpts have been selected from the decisions of the Supreme Court in this important case: "The petitioner contends that there was no express contract and that it can recover *quantum meruit* for the reason that the minds of the parties never met on the matter of the thickness of the core." However, the court decided in spite of any ambiguity in the language of the contract which the parties saw fit to sign that "The fact that an executed written contract contains within itself difficulties of construction about which the parties disagree does not enable a party to contend that the minds never met. By signing the writing the parties bind themselves to such interpretation as the court may place upon the words and symbols employed by them." Referring to the provision that the engineer should decide all questions which might arise as to the interpretation of the plans and specifications, the court found that "The engineer's decision does not appear to have been arbitrary or made in bad faith. The petitioner is bound by it." As in the first case, referred to above, the contractor discussed borings, borrow pits and probable requirements with a number of the engineers and claimed that he counted on starting and being allowed to continue to operate in the lower and most conveniently located borrow pits. He even claimed the right to rescind the contract for fraud because, as he contended, the engineers had decided in advance that these lower borrow pits would probably not continue to be suitable, but had failed to so notify him. The court found that "The petitioner was fully informed that if it bid on the assumption that it could build the entire embankment from the lower area it would do so at its own risk", and that there was "no preponderating proof that the petitioner would have declined to bid or would have altered its figures or would have been influenced in any material degree if the so called decision had been disclosed to it."

In denying the contractor's claim for a breach of implied warranty, the court took into account the "express statements on the plans and in the contract to the effect that the existence of a sufficiency of suitable material in any one area is not guaranteed; that the contractor will be allowed to borrow from any one area only to the extent that the materials are acceptable and satisfactory", and noted further that "Besides these, there are general provisions that the engineer shall decide all questions as to the quality, acceptability, and fitness of the materials to be furnished, and that the entire work shall be completed to the satisfaction of the engineer."

In denying the contractor's claim that the orders of the engineers lay sufficiently without the scope of their powers as to constitute a breach of contract, the court decided that "Since it appears that the orders of the engineers were within the scope of powers granted to them as defined by the contract, the only remaining inquiry is whether they have actually exercised the judgment committed to them without compulsion, deception, or fraud on the part of others and in good faith on their own part." The Auditor, before whom the case was first heard, had found in several instances that the decisions of the engineers were unreasonable and unnecessary.

The decision of the court upon this point is very illuminating. The court noted that the Auditor intentionally refrained from going further than that and also that he made the statement in accordance with his (the Auditor's) opinion, formed from the evidence before him, that the engineers' decisions were not in accordance with, or demanded by, good engineering judgment. The court decided that "There is no finding that any of the decisions complained of was arbitrary, capricious, or tainted by compulsion or fraud", and went on to say that "The case must therefore be dealt with on the footing that all decisions of the engineers were made in the actual free exercise of good faith of their own best judgment. Neither reasonableness in the ordinary sense nor necessity determines the limits of the engineers' powers or the validity of their exercise. This is not a case where work is to be done to the satisfaction of a party to the contract and where the contract is interpreted, if possible, to mean reasonable satisfaction." The court concluded that the decisions of the engineer "are not to be controlled by any extrinsic standard of reason or necessity. That would merely substitute the judgment of court or jury for that of the engineer", and that "For a court to substitute its own lay opinions on such matters, however well it may think itself informed through evidence, for the opinions of the engineers in the field to whom the parties have entrusted such decisions would be directly contrary to the terms of the contract and in the long run likely to produce unsound results."

One should not conclude from the above remarks about three court actions that we have had unusual difficulties with our contractors. Quite the contrary is true. We have executed about 146 construction contracts, many of them greater in value than the three discussed, and our relations have been most satisfactory. I am well aware of the fact that there is a growing complaint by contractors against the current forms of public works contracts. I believe that such complaints are in many cases well founded and I would be in favor of modifications which would assure both parties of fair and competent arbitration of disputes. Quoting again from the Supreme Court's decision in one of the cases above referred to, "The engineers, at least with respect to the decisions complained of, are made quasi arbitrators by whose judgment the parties agree in advance to be bound." Speaking for myself, and for my distinguished predecessor Mr. Winsor, we have taken very seriously this role of impartial arbiter, and have always done our best to interpret disputed provisions fairly to both parties. In approving estimates for our contracts which have totalled about $43,400,000, there have been many occasions when we have leaned over backward to see that the contractor who has placed his trust in us gets a square deal. It has been in the best interest of the Commission and the Commonwealth that we have done so.

## ASSESSMENTS AGAINST THE MEMBER MUNICIPALITIES IN THE WATER DISTRICT

What has been the effect of all this on the cost of water to the towns in the Water District? The old Wachusett-Sudbury development was financed by the issue of 40-year sinking fund bonds which had not been paid off when the new work started. The necessity for heavy expenditures to pay for the old works was not materially reduced until 1936. In the meantime serial bonds for the new supply had been issued, and the term of these bonds was not more than 30 years. In fact the first of these bonds issued were for only a 20-year term. The resulting increase in cost was undoubtedly one reason why no new towns joined the District to help share this cost The cumulative effect was to almost double the annual assessments which reached a total of about $5,000,000 in the years 1935 to 1938. The District's water assessments have nothing to do with state taxes and are met entirely by the consumers of the water.

One interesting fact about these assessments is that the financing of such permanent and lasting developments as the Ware-Swift supply by such relatively short term bonds insured a decade of very high costs, but also insures, with equal certainty, a rapid subsequent drop in the assessments. However, the anticipation of much lower costs in the next 20 or 30 years has not been sufficient to attract new customers now. The cost per million gallons had been approximately $55 for many years prior to the development of the new supply, but it rose to about $105 in 1934 and remained at approximately this high level until 1938. However, in the next 6 years it had dropped to about $80. The Legislature in 1946 radically amended the statutes to provide a fixed rate of only $40 per million gallons by the annual issue of so-called water-use-development bonds which have the same effect as refinancing bonds. This plan is feasible only because of the assured reduction in the requirements of the construction bonds.

The crux of the matter lies in the effect on the net debt, which has never been less than $20,000,000 since the District was organized and which should again drop to that figure even though an additional appropriation of $10,000,000 every 15 years could delay the drop and spread it over 40 years.

There have been so many inquiries about the various amendments which affect the matter of water assessments that the writer has prepared the following brief summary of the provisions of Chapter 587 of 1945, as amended by Chapter 549 of 1946.

## Metropolitan Water Supply

### Brief Summary of the Provisions of Chapter 587 of 1945, as Amended by Chapter 549 of 1946.

These acts amend Sections 10 and 26 of Chapter 92 of the General Laws retaining certain amendments of a similar character that were made by Chapter 543 of the Acts of 1943.

They allow, in addition to supplying new members, the sale of water from the distribution system to eligible non-members in an emergency.

Keep the provision of Chapter 543 which extends the eligibility to membership in the water district from the 10-mile radius to the 15-mile radius to the extent that the District has extended, or can reasonably extend, its distribution system; and also the clear definition of membership in the District, members being towns admitted upon their formal application.

Make both members and eligible non-members subject to annual assessments by the state treasurer, whereas non-members were formerly merely billed for water purchased.

Make no specific provisions for the sale of district water from any part of the collection system other than the distribution system; but this is left to approval of the State Department of Public Health.

Clarify the present liability of all new users to pay the cost of connection to the District's distribution system.

Keep the provision whereby payments for costs of connection by towns who want Metropolitan water, whether or not they are eligible to join or do join the District, can be spread over a period of 10 years. This applies also to any entrance fees.

Allow water supply connections between member and non-member towns without restriction; and eliminate the standby charge to

### ACTUAL AND ESTIMATED GROWTH OF THE METROPOLITAN WATER DISTRICT AND WATER CONSUMPTION IN MILLION GALLONS DAILY

| | 20 Cities and Towns Now Members of Metropolitan Water District | | | | | Total M.G.D. Supplied in the Metr. Area from the Distribution System | | Additional M.G.D. supplied from the Watersheds, and from the Reservoir and Aqueduct Systems | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | To Worcester By Pumping from | | |
| | Population | Gallons Per Capita Daily (and Per Cent of Services Metered) | Total M.G.D. consumed | Credit M.G.D. from Local Sources | M.G.D. to Towns Expected to Join the District after 1947 | To Members | Other than members. Some of this included in the assessment commencing 1946 | To Natick Hospitals, etc., except to Worcester | Wachusett Res. | Quinapoxet Area | Total M.G.D. taken from District Sources, incl. the Quinapoxet Area from which Worcester has right to take 10 m.g.d. and incl. the South Sudbury |
| 1895 | 779,581 | 90.6 | 70.82 | | | | | | | | |
| 1900 | 897,475 | 111.4( 8) | 100.0 | | | | | | | | |
| 1905 | 974,877 | 125.3( 11) | 122.13 | — 6.05 | | 116.08 | | 1.88 | | | 117.96 |
| 1910 | 1,098,048 | 107.6( 38) | 118.22 | — 6.13 | | 112.09 | | 0.87 | | | 112.96 |
| 1915 | 1,234,790 | 87.1( 67) | 107.52 | — 5.58 | | 101.94 | | 1.06 | 0.13 | | 103.13 |
| 1920 | 1,290,651 | 104.1( 74) | 134.40 | — 7.13 | | 127.27 | | 1.38 | | | 128.65 |
| 1925 | 1,398,702 | 97.6( 96) | 136.52 | — 7.66 | | 128.86 | 0.06 | 3.00 | 2.58 | | 134.50 |
| 1930 | 1,498,253 | 97.5( 99) | 146.11 | — 8.95 | | 137.16 | 0.37 | 3.19 | 2.39 | | 143.11 |
| 1931 | | 95.8( 99) | 144.57 | — 9.45 | | 135.12 | 0.36 | 2.41 | 0.20 | | 138.09 |
| 1932 | | 90.7(100) | 137.68 | — 9.27 | | 128.41 | 0.38 | 2.69 | | | 131.48 |
| 1933 | | 88.0 | 134.39 | — 8.97 | | 125.42 | 0.43 | 2.79 | | | 128.64 |
| 1934 | | 93.2 | 143.14 | — 9.39 | | 133.75 | 0.44 | 2.98 | | | 137.17 |
| 1935 | 1,548,282 | 90.9 | 140.71 | — 9.44 | | 131.27 | 0.45 | 3.43 | | | 135.15 |
| 1936 | | 92.9 | 143.48 | — 9.62 | | 133.86 | 0.47 | 3.39 | | | 137.72 |
| 1937 | | 91.5 | 140.29 | — 9.17 | | 131.12 | 0.47 | 3.28 | | | 134.87 |
| 1938 | | 91.5 | 139.40 | — 9.15 | | 130.25 | 0.47 | 2.96 | | | 133.68 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1939 | | 96.0 | 145.44 | — 9.41 | | 136.03 | 0.53 | 3.92 | | | 140.48 |
| 1940 | 1,511,667 | 98.7 | 149.16 | — 9.68 | | 139.48 | 0.57 | 3.46 | | | 143.51 |
| 1941 | | 102.4 | 155.70 | — 9.76 | | 145.94 | 0.89 | 3.01 | 1.17 | 0.75 | 151.76 |
| 1942 | | 105.4 | 161.28 | — 9.77 | | 151.51 | 0.61 | 3.38 | 0.76 | 8.60 | 164.86 |
| 1943 | | 109.4 | 168.39 | —10.09 | | 158.30 | 0.90 | 3.51 | | 4.16 | 166.87 |
| 1944 | | 111.9 | 173.30 | — 9.99 | | 163.31 | 1.47 | 3.33 | | 6.59 | 174.70 |
| 1945 | 1,558,287 | 111.8 | 174.13 | — 9.90 | | 164.23 | 1.33 | 3.31 | | 0.82 | 169.69 |
| 1946 | | 113.5 | 177.88 | —10.09 | | 167.79 | 1.33* | 3.91 | | | 173.03 |
| 1950 | 1,600,000 | 113 | 181 | — 6 | 6 | 181 | 1 | 4 | | 6 | 192 |
| 1955 | 1,660,000 | 114 | 189 | | 24 | 213 | 1 | 4 | | 8 | 226 |
| 1960 | 1,710,000 | 115.5 | 197 | | 28 | 225 | 1 | 4 | | 10 | 240 |
| 1965 | 1,750,000 | 117 | 205 | | 31 | 236 | 1 | 4 | | 10 | 251 |
| 1970 | 1,780,000 | 118 | 210 | | 33 | 243 | 1 | 4 | | 10 | 258 |
| et seq | | | | | | | | | | | |

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*Incl. .08 taken by Winchester which was admitted, as the 21st town, but only for the supply of its West Side.

non-member towns within reach of the distribution system of the District, which are given or continue to have connection with the system, and leave the question of such connections entirely a matter of approval by the Department of Public Health.

Eliminate any difference between the price of water supplied regularly to members and that supplied in an emergency to eligible non-members.

Keep the provisions which allow the District to admit without any entrance fee a town entering and taking its entire supply from the District, and which materially reduce the entrance fee in the case of a town entering the District without abandoning its local supply. However, the provision eliminating any difference in cost as between members and eligible non-members amounts to a practical elimination of the entrance fee.

Keep the clarified definition of valuation. However, the provisions which eliminate valuation as a factor in assessments and which, in effect, eliminate all entrance fees, leave no other use for the word valuation.

Provide for optional agreements between the District and towns which do enter, under which the Commission may acquire water supply works and lands of the town which are of value for any purposes of the Metropolitan District Commission, its Sewerage and Parks Division, as well as its Water Division. Such works are to be taken over at cost, which if not agreed upon shall be determined by appraisal commissioners appointed by the Supreme Judicial Court.

Provide that instead of receiving cash for such works, the entering town shall receive credit on its water assessment spread over a period of 25 years with interest at 1½%.

Provide, in case such abandoned works are not acquired by the District, that the town may dispose of them without restriction on account of prior dedication to water supply purposes, and a similar provision permits the Commission to dispose of any portion of the property so acquired that is not of value to the Commission.

Provide that when the Commission makes any such sale it must give the town that originally owned the works the first opportunity to buy them back.

Provide that works so taken on account of their usefulness to the Sewerage or Parks Division of the Commission shall be compensated for by assessments upon the towns in the Sewerage or Parks Districts respectively, and not upon the towns in the water district. The state Treasurer will include in such assessments the same interest spread over 25 years as he credits to the new member of the water district.

Make adequate provision for the transfer to the Metropolitan District Commission, without loss of pay or impairment of civil service status, of employees from the Water Department of towns whose facilities are abandoned upon entry into the District.

Provide for a reduction, commencing in 1946, in the water assessment to a fixed $40 per million gallons by issuing annually so-called water-use-development bonds. These are expected to aggregate about $40,000,000 over a period of about 25 years.

Eliminate the distinction between member towns of relatively high and of relatively low valuation which has heretofore resulted in wide discrepancies in the assessment per million gallons, varying recently from about $75 to $125 per million gallons.

Eliminate all the special provisions applying to the assessment of member towns taking only a portion of their supply from District sources, the only basis of assessment being the fixed price per million gallons.

Continue, of necessity, the basing of assessments, against member towns taking their entire supply from the district, on the average rate of consumption during the previous calendar year, although the assessments are, as always, in payment for use during the year of assessment.

Make available each year, to reduce the amount of the water-use-development bonds, the surplus in the sinking fund, which already amounts to about $550,000, and which will continue until the last sinking fund bonds mature in 1950, instead of allowing this surplus to accumulate to well over a million dollars at that date of final maturity.

Continue the existing provisions by which up to $250,000 a year are made available to the District for constructing water supply connections in anticipation of reimbursement over a period of ten years by the town paying for the connection.

The water district now offers to new customers not only the attractive price of $40 per million gallons, but a water supply of excellent quality. The policy of constructing Quabbin Reservoir without stripping the soil from the bottom has been fully justified. The quality of the water is the subject of a recent paper by Superintendent

Clarence H. Reed of the Sudbury Division published in the Journal of the New England Water Works Association for June 1947. Quabbin Reservoir has improved rapidly during the filling and after 3½ years of filling the results of analyses show a relatively stable condition has been reached with a vast improvement in the reduction of mineral salts such as iron and manganese. The color is stabilized at only 13 parts per million and dissolved oxygen is above 80 per cent saturation in the deep portion of the reservoir near Winsor Dam.

# PLANNING THE AIRPORT SITE

By A. J. Bone*

(Presented at a meeting of the Transportation Section, B.S.C.E., held on April 17, 1946.)

THE first step in the design of an airport is to determine the use that is to be made of it. This involves a knowledge of the types of airplanes to be accommodated and the volume of air traffic to be expected. In general, airports fall into three categories: those serving commercial air traffic almost exclusively, those serving both commercial and private flying, and those serving private flying of a recreational nature and pilot training. The airport requirements for these several activities vary greatly, both with respect to the size of the airport and the facilities which are needed.

The Civil Aeronautics Administration (C.A.A.) has set up a classification of airports based upon runway length. This classification is defined briefly in Table I. The larger cities will ultimately have one or more airports of class 4 or 5 devoted to commercial use and also a number of smaller airports of classes 1, 2 and 3 for local air service and for private flying. The smaller cities will probably have one major airport of class 3 or 4 serving all classes of flying and a few smaller airports of classes 1 and 2 for private flying only. The smaller communities will have the smaller airports of classes 1 or 2 for private flying and limited local air service using small planes. In some regions one airport may serve two or three adjacent towns.

## SELECTION OF AIRPORT SITE

The selection of an airport site will be influenced by a number of factors; such as the area required, possibility of expansion, accessibility to the community, absence of obstructions in approaches, freedom from fog and smoke, nature of the terrain, nearness of other airports and cost of construction.

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Table I—Civil Aeronautics Administration Airport Planning Classification Design Standards Recommended for Different Types of Communities

| *Planning Classification* | *Recommended Landing Strip Lengths at Sea Level Clear Approaches** | *Type of Community That May Be Served* | *Type of Aircraft Which Airport May Safely Accommodate* |
|---|---|---|---|
| 1 | 1800′ to 2700′ | Small communities not on present or proposed scheduled air carrier system, and auxilary airports in larger metropolitan areas to serve nonscheduled private flying activities. | Small private owner type planes. This includes roughly planes up to a gross weight of 4000 pounds, or having a wing loading (lbs./sq. ft.) times power loading (lbs./HP) not exceeding 190. |
| 2 | 2700′ to 3700′ | Larger communities located on present or proposed feeder line airways and which have considerable aeronautical activity. General population range 5,000 to 25,000. | Large size private owner planes and some small size transport planes. This represents roughly planes in the gross weight classification between 4000 and 15,000 pounds, or having a wing loading (lbs./sq. ft.) times power loading (lbs./HP) of 190 to 230. |
| 3 | 3700′ to 4700′ | Important cities on feeder line airway systems and many intermediate points on the main line airways. General population range 25,000 to several hundred thousand. | Present day transport planes. Planes in this classification are represented approximately by those between 10,000 and 50,000 pounds gross weight, or by those having a wing loading (lbs./sq. ft.) times power loading (lbs./HP) of 230 and over. |
| 4<br>and<br>5 | 4700′ to 5700′<br>5700′ and over | Cities in this group represent the major industrial centers of the nation and important junction points or terminals on the airways system. | Largest planes in use and those planned for the immediate future. This approximately represents planes having a gross weight of 74,000 pounds and over or having a wing loading (lbs./sq. ft.) times power loading (lbs./HP) of 230 and over. |

*Approaches shall be clear within a glide path of 20 to 1 from the end of the usable area in the case of Class 1 airports and 30 to 1 in the case of Classes 2, 3, 4 and 5 airports except for instrument landing runways for which the ratio shall be 40 to 1. These ratios represent the minimum permissible. In all cases it is highly desirable to clear approaches to runways on as flat a ratio as is possible in the interest of safety. A 50 to 1 ratio is a desirable minimum.

NOTE:—Paved runways shall be 200′ shorter than landing strips.

Source:—Airport Design Information, Civil Aeronautics Administration, April 1, 1944.

## AREA REQUIRED

The area needed is determined principally by runway length requirements. These are correlated, in a general way, with the size of the community and type of aircraft in the Classification of Airports given in Table I.

A small airport of the class 1 type with minimum landing strip length of 1800 ft. may be located on areas from 50 to 160 acres provided the approaches meet the C.A.A. standards. Such airports will probably effectively serve up to 100 private planes based at the airport. If more private planes are to be provided for, additional sites should be sought at dispersed locations convenient to the owners, rather than attempting an extensive enlargement of the original field.

Class 2 airports require from 200 to 300 acres; class 3 airports from 350 to 500 acres; class 4, about 640 acres (one square mile); and class 5 airports with runways ranging from 7,000 to 10,000 feet in length may cover several thousand acres. The above areas are for sites near sea level. Longer runways and therefore larger sites are required at the higher altitudes. Table II shows the areas and runway

TABLE II—AREAS AND RUNWAY LENGTHS AT CERTAIN MUNICIPAL AIRPORTS

| *City* | *Name of Airport* | *CAA* Class* | *Area (Acres)* | *Number of Runways* | *Longest* | *Shortest* |
|---|---|---|---|---|---|---|
| New York, N. Y. | La Guardia | 5 | 584 | 4 | 6000 | 3530 |
| | Idlewild | 6† | 4527 | 12† | 11,200 | 6000 |
| Washington, D. C. | National | 6 | 650 | 4 | 6855 | 4100 |
| Chicago, Ill. | Municipal | 6 | 630 | 9 | 6546 | 4639 |
| St. Louis, Mo. | Lambert | 5 | 521 | 3 | 5600 | 2800 |
| Buffalo, N. Y. | Municipal | 5 | 549 | 4 | 5642 | 3645 |
| Cleveland, O. | Municipal | 5 | 1200 | 7 | 6000 | 5008 |
| Pittsburgh, Pa. | Allegheny Co. | 5 | 150 | 4 | 5740 | 2519 |
| Columbus, O. | Port Columbus | 4 | 543 | 4 | 5000 | 3550 |
| Detroit, Mich. | Municipal | 4 | 270 | 3 | 5280 | 2825 |
| Indianapolis, Ind. | Weir Cook | 4 | 1015 | 4 | 4848 | 3650 |
| Cincinnati, O. | Lunken | 3 | 425 | 3 | 4063 | 2700 |
| Toledo, O. | Municipal | 3 | 513 | 3 | 4224 | 2995 |
| Louisville, Ky. | Bowman | 3 | 300 | 3 | 4350 | 3600 |
| Harrisburg, Pa. | State Airport | 3 | 255 | 3 | 4000 | 3750 |
| New Haven, Conn. | Municipal | 3 | 388 | 2 | 4200 | 4100 |
| Portland, Maine | Municipal | 3 | 328 | 3 | 4300 | 3500 |

*Class based on longest runway Class 6 includes runways over 6500 ft. long.
†First stage 3 runways; second stage 6 runways; third stage 12 runways.

lengths at a number of existing airports used by the scheduled airlines. Many of these areas are much smaller than desirable, because sites were chosen in locations where expansion proved impracticable.

## Possibility for Expansion

Many airports are obsolete for commercial air transport because they are on sites that cannot be expanded because of physical limitations or for economic reasons. Some are bounded by built-up land which can only be obtained for airport use at excessive cost, other airports are adjacent to natural obstacles, such as mountains, rivers, harbors, railroad yards, or factories. Sites adjacent to rivers or harbors may be enlarged by using fill to make additional land, but this process is very costly.

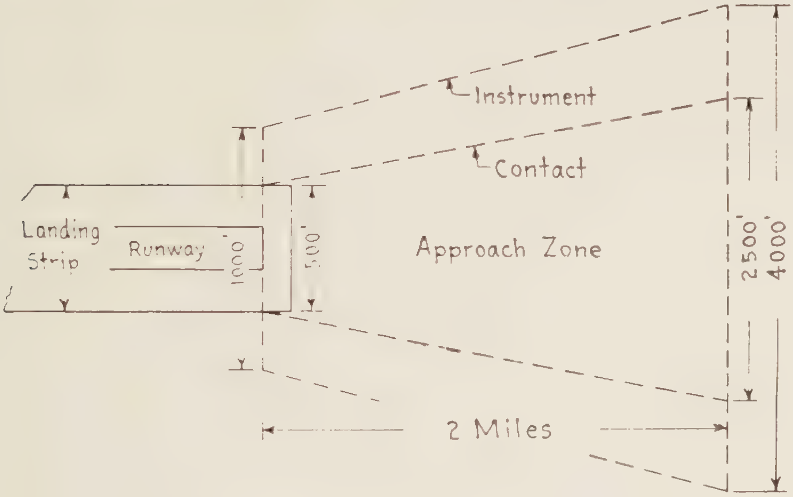
In selecting a new site, a location should be chosen that will permit expansion at reasonable cost. Ample land should be available for purchase. It is advisable to take more land than is immediately necessary in order to prevent uncontrolled industrial or residential growth adjacent to the site. Land that is not needed for airport facilities may be rented for farming or other purposes, thus bringing in some revenue. Excess land may be developed into recreational areas, such as parks, picnic grounds or a golf course.

## Terrain

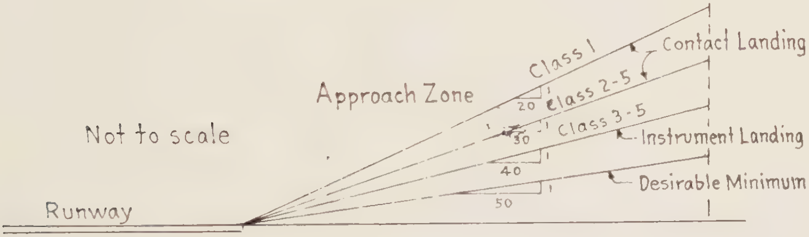
As airports are practically flat surfaces, a relatively level site is desirable for low grading cost. The C.A.A. specifications limit the slope of runways to 1½% with very gradual changes in grade (Table IV) thus allowing very little opportunity to adjust airport grades to the topography. Ridge or hilltop sites usually have the advantages of clear approaches for airplanes and good natural drainage. Large, flat areas, however, are usually to be found in lowlands, such as swamps. These offer poor foundation soil for an airport and require expensive filling and drainage. Frequently there is no large, open tract available near a large city except tidal land or river marsh. Some of the largest airports, such as those at New York, Boston, and Washington, are built on sites that were created by filling in waterfront areas.

### APPROACHES

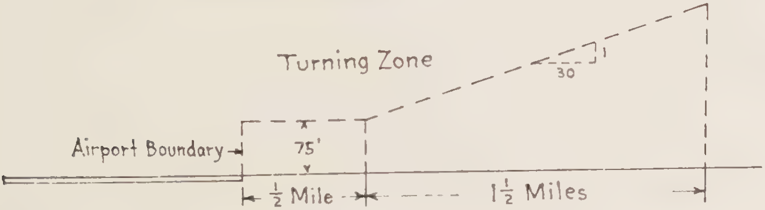
The terrain surrounding the airport site is of equal importance to that of the site itself. A flat site hedged in by mountainous terrain, or by tall buildings and factory chimneys, will not permit the clear approaches necessary for the safe use of the airport. Minimum approach standards recommended by the C.A.A. are illustrated in Fig. 1



(a) Plan - End of Runway and Approach Zone



(b) Profile - Glide Path Slopes



(c) Profile - Turning Zone Limits - Between Approach Zones

FIG. 1.

(a) and (b). Two sets of standards are prescribed: one for runways to be used in clear weather under "contact" flying conditions, and another for runways to be used in overcast (as well as clear) weather when visibility is limited and pilots must rely on their instruments and radio directions when approaching the runway. For contact flying, the approach zone is a trapezoidal area starting with a width of 500 ft. at the end of the runway and broadening to 2,500 ft. at a distance of 2 miles. Within this zone there should be no obstacles protruding above a plane rising from the end of the runway on a slope of 1 in 20 for class 1 airports, and 1 in 30 for all other classes. The instrument flying approach zone is 1,000 ft. wide at the end of the runway, broadens to 4,000 ft. in 2 miles, and rises on a slope of at least 1 in 40. Between the approach zones, obstructions should be kept below the heights shown in Fig. 1 (c) for turning zones.

Fig. 2 shows the approach and turning zones for an airport drawn over the topography of the surrounding region. Elevations are shown along the bottom of the approach zones. When these are compared with the contour elevations on the ground, high areas may be detected. The runway approach zones are clear for instrument runways, but there are four high spots in the turning zones. The illustration is for an essentially rural area. In testing the approaches of a city airport, a plot must be made showing the locations and elevations of all man-made structures within a radius of several miles of the airport site. Little can be done to remove existing structures. They must be avoided as far as possible in the orientation of the runways. Precautions should be taken, however, to protect approaches against future intrusions by instituting rigid zoning. The legality and effectiveness of existing zoning laws is an important factor in site selection.

## Nature of Site—Culture and Soil

From the standpoint of construction cost, the site, if possible, should be on cleared ground that is easily drained and which will offer a satisfactory subgrade for runway surfaces. Soils of a sandy or gravelly nature are preferred, as they are easily drained and form satisfactory bases for pavements. Silty and clay-like soils are less desirable, and organic peat is to be avoided unless it can be readily removed. A site that slopes gently into natural drainage channels, such as brooks and streams, is to be preferred to a large, flat swampy area that will require an expensive artificial drainage system. Sites

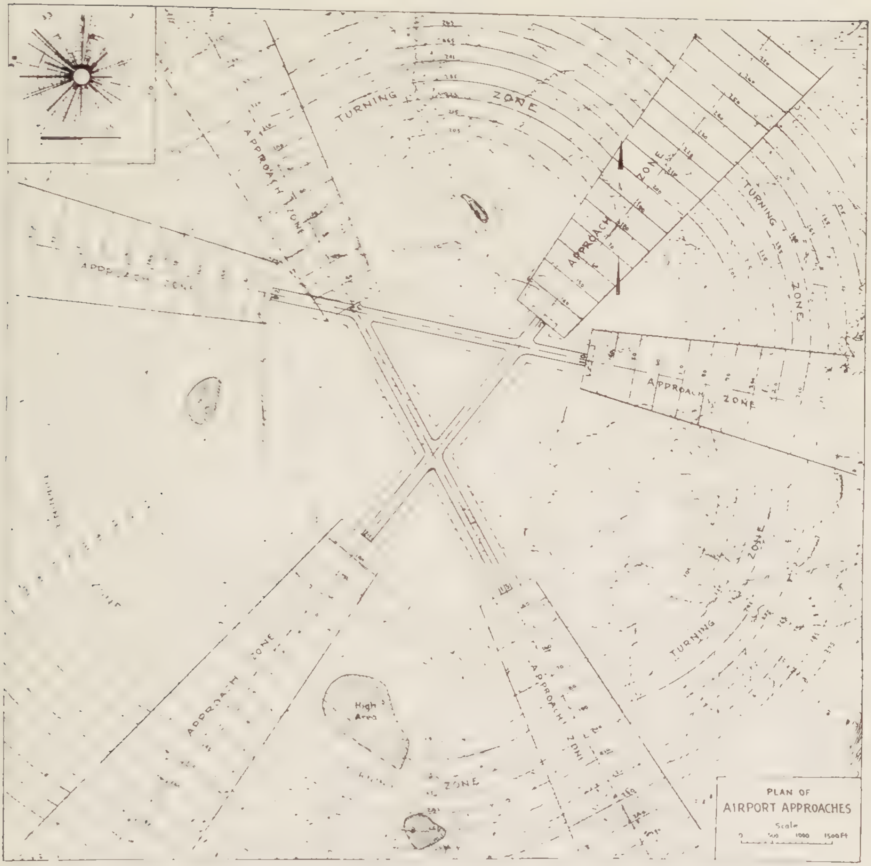


Fig. 2.

should be high enough above river bottoms to prevent flooding. Ledge rock is to be avoided because of the expense of rock excavation. A site near local gravel deposits or a stone quarry is desirable since large quantities of these materials are needed in construction.

## ACCESSIBILITY

The outstanding advantage of air transportation is speed. Unless airports are readily accessible to the community which they serve, much of the advantage of air transportation will be lost in the time consumed in getting to and from airports at each end of the air trip. The accessibility is measured in time rather than in distance. Generally speaking, the nearer the airport to the community center the shorter will be the time to reach the airport. This is not necessarily true, however. An airport may be located near the center of a large city, yet be so surrounded by traffic-congested streets, that access is slow and tortuous. On the other hand, an airport located well outside the city limits, but on an express highway to the city, may be reached in less time than one on an in-town site. Before any site is selected the ground transportation system should be thoroughly studied, both as it exists and as it may be improved in the immediate future. Time studies should be conducted by driving over the routes to the proposed site, particularly during peak traffic hours.

Close-in sites usually involve taking high-priced property. In other instances they require expensive filling of marsh or tidal areas. The cost of land acquisition and grading should be compared with the cost of super-highway construction to a more distant site.

An overall study of the metropolitan area should be made to determine the present and future demand for air traffic including the relative demand from the central business area and the several suburbs. The site, if possible, should be chosen in a location most accessible to the greatest number of potential air passengers.

The airport site selection is closely tied in to the transportation for the community as a whole, and to regional planning in general. A site should not be selected that will block a desirable development of the city plan. The size of the airport site is such as to interrupt the street layout over a large area, in much the same way that a freight yard interferes with the continuity of the street pattern. The airport, however, cannot be bridged as can the freight yard.

If the air traffic is predominately to and from a particular direction, such as to the southeast, a site on that side of the community will reduce the air distance (and time) for a majority of passengers and also reduce the noise of planes over built-up areas, and the hazard to planes in flying over high buildings and stacks in overcast weather. The selection of a site in outlying areas is less likely to arouse opposition than one adjacent to residential districts. Another advantage of a rural location is that it provides ample space for a logical development of service facilities and other activities related to aviation.

## Effect of Airport Site on Land Values

The presence of an airport may reduce the value of land for some purposes and increase it for others. In the present state of development the airplane is inherently noisy and the noise is heard over large areas; more so than the noise of other forms of transportation vehicles that are confined to narrow paths. A proposal to locate an airport in or near a residential area is almost sure to encounter opposition from many of the residents. This opposition may grow as airplanes increase in number and the noise becomes more intense. For many years to come the users of airplanes, particularly small planes, will be a very small percentage of the population. The value of land near an airport, is therefore, likely to decline for residential purposes. On the other hand, the creation of an airport on undeveloped land remote from residences will create new values in such land as sites for activities related to the airport, such as for hangars, shops, sales rooms, club houses, restaurants, observation areas, and possibly park and recreation areas. The airport will become a center of attraction not only for the users of private planes, but also for the larger group of the interested public who wish to watch the activities of the airport and occasionally indulge in sight-seeing or charter flights.

The possibility of developing such land values and the value of the improvements thereon should be considered in site selection. The opposition of residents and the attendant loss of values in existing developed areas is to be avoided The principal argument for locating airports near residential areas is ease of access. Proximity to the airport is not necessarily essential for ready access. People will reach the private airport almost exclusively by private automobile. The very size of the airport precludes walking to the airport from adjacent homes. Hence the trip to the airport will be a motor trip, and since roads to rural sites are usually free of congestion, speeds will be high.

## Availability of Services

The airport facilities, terminal, hangars, shops, etc., comprise an industrial unit which will require services, electric power, telephone, water, sewers, and public transportation. The availability of these services is a factor in site selection. If other factors are controlling, however, the demand created by new airport facilities will warrant bringing services to the site.

## Spacing of Airports

Airports should not be spaced too closely because a zone around the airport is needed for the maneuvering of planes in approaching the airport, particularly in instrument flying weather. The C.A.A. prescribes a traffic pattern for each airport. These should not conflict. Radio communications between planes and airport control towers are also complicated when airports are too close together. The C.A.A. has recommended the following radii for traffic patterns for contact flying conditions:

| *Class* | *Radius* | *Minimum Spacing* |
|---|---|---|
| 1 | 1 mile | 2 miles |
| 2 | 2 miles | 4 " |
| 3 | 3 " | 6 " |
| 4 | 4 " | 8 " |

In instrument flying weather, greater precautions are required and more space is desirable for maneuvering. A spacing of 14 miles is recommended when scheduled airlines make frequent instrument landings. No fixed rule can be laid down, however, as each situation should be studied in the light of local conditions.

## Economics of Site Selection

Airports are costly projects. If alternate sites appear to meet minimum operational requirements, the selection should be thoroughly studied from the standpoint of cost. Not only is the first cost of importance, but also the long-run or economic cost, which includes maintenance and amortization as well as interest on the initial investment.

Factors influencing the initial cost are airport size which is dictated by the types of planes to be accommodated and the volume of air traffic; land costs which will vary widely depending upon the state of improvement of the land and its real or potential value for home sites or industrial purposes; grading and drainage whih depend on the nature of the terrain (flat or hilly) and the character of the soil; length of highway connections and ease of their construction; difficulty in extending services to the airport site, and availability of local labor and materials for use in paving and building construction.

## Summary of Factors Influencing Selection of Airport Site

The various factors to be cosidered in selecting an airport site are tabulated in Table III. As an aid to judgment in selecting a site, columns are added at the right for rating each of the characteristics of alternate sites, such as A, B and C. As all of the items in Table III are not of equal importance, a column is provided for weighting factors (W). The weights and ratings entered in the table are for illustration only. The emphasis to be given to one requirement over another will depend upon the class of airport under consideration and upon the judgment of the investigator as influenced by his experience and knowledge of local conditions.

The individual sites A, B and C have been rated according to preference: first, second or third choice. With respect to some characteristics, two or even three of the sites may be of equal desirability. When this is so, one site would be rated 1 and the remaining two sites rated 2, or if all three sites are equally satisfactory, they would all be rated 1. Instead of expressing a choice, the alternate sites could be rated on a percentage basis,—provided there is sufficient information available to warrant this refinement. For example, if the terrain requirements are wholly satisfactory at site C, it would be rated 100, if they were not quite so good at B, that site would be rated 80, and if they were poor at A, that site would be rated 50. The final rating is found by adding the products of the weighting factors (W) and the individual ratings (R).

## Reconnaissance for Airport Sites

The first step in seeking likely airport sites will be an examination of the best available maps of the region. Recent issues of U. S. Geological Survey maps to the scale of 2 inches = 1 mile (1:31680) are well adapted for this purpose. Valuable information may also be obtained from aerial photographs which show buildings and culture in great detail. If stereo-pairs of photographs are taken, the terrain and all features on it may be viewed in three dimenions in the stereoscope. With the proper instruments, a complete contour map may be drawn from these photographs. Heights may also be scaled of buildings, towers and trees which are located in the approaches.

TABLE III—RATING TABLE FOR FACTORS INFLUENCING SELECTION OF AIRPORT SITE

| Item | Factor | *Weight per Item* | *Rating (R) 1 = 1st Choice Sites* | | | *Products of WR Sites* | | |
|---|---|---|---|---|---|---|---|---|
| | | *W* | *A* | *B* | *C* | *A* | *B* | *C* |
| 1 | *Terrain:* Ease of grading and draining—freedom from topographical obstacles such as hills, ledge, ravines, streams, peat bogs, etc. | 10 | 3 | 2 | 1 | 30 | 20 | 10 |
| 2 | *Approaches:* Freedom from obstacles in approach and turning zones—proximity to airways and direction of major air traffic flow. | 15 | 2 | 1 | 1 | 30 | 15 | 15 |
| 3 | *Meteorology:* A minimum of fog, smoke, gusty or shifting winds, heavy snows and frequent freeze and thaws. | 5 | 3 | 2 | 1 | 15 | 10 | 5 |
| 4 | *Possibility of Expansion:* Availability of sufficient airport land—absence of natural and man-made barriers preventing expansion—adaptability of site to the requirements of the master plan. | 10 | 2 | 3 | 1 | 20 | 30 | 10 |
| 5 | *Accessibility:* Time and distance from center of city or town—time and distance to residential areas—convenience for majority of users—proximity to highway and rail transportation, existing and proposed—availability of public transit. | 15 | 1 | 3 | 2 | 15 | 45 | 30 |
| 6 | *Land Values:* Possibility of increasing value of airport and adjacent areas—possibility of decreasing existing values—likelihood of blocking development of city plan—possible loss of tax revenue. | 5 | 1 | 2 | 3 | 5 | 10 | 15 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 7 | *Control of Site:* Possibility of protecting approaches and adjacent areas by zoning—availability of right of eminent domain—necessity for cooperative action by other government agencies—their attitude. | 10 | 1 | 3 | 2 | 10 | 30 | 20 |
| 8 | *Other Airports:* Proximity of other airports, existing and proposed—relation of site to airport plan for region. | 5 | 1 | 1 | 1 | 5 | 5 | 5 |
| 9 | *Utilities:* Availability of water, sewer, power and communication services. | 5 | 1 | 2 | 3 | 5 | 10 | 15 |
| 10 | *Nature of Soil:* Suitability for grading, subgrade for paving and foundations for buildings—ease of drainage. | 5 | 3 | 2 | 1 | 15 | 10 | 5 |
| 11 | *Cost of Development:* Land, grading, drainage and paving—availability of labor and materials—maintenance and operating expenses—annual economic cost. | 15 | 3 | 2 | 1 | 45 | 30 | 15 |
| 12 | Weighted Average Rating (Sum of W × R for each item). | 100 | | | | 195<br>2nd | 215<br>3rd | 145<br>1st |

## Layout of the Airport

The essential features of an airport are the runways on which the airplanes land and from which they take off; the taxiways connecting runways with the terminal area; the paved apron at the terminal on which the airplanes are loaded, unloaded and serviced; the terminal buildings for housing airport activities and handling passengers, mail and cargo; hangars and shops for reconditioning planes; parking lots and driveways for use of patrons, employees and visitors.

The C.A.A. has recommended standards for runway width, length and direction, drainage, paving, lighting, communications and terminal facilities. These standards are summarized in Table IV.

Table IV—Civil Aeronautics Administration Airport Standards for Physical Characteristics of Different Classes of Airports

| Recommended Standards | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
|---|---|---|---|---|---|
| Length of landing strips[1] | 1800′ to 2700′ | 2700′ to 3700′ | 3700′ to 4700′ | 4700′ to 5700′ | 5700′ and over |
| Width of usable landing strips | 300′ | 500′ | 500′ | 500′ | 500′ |
| Length of runways | None | 2500′ to 3500′ | 3500′ to 4500′ | 4500′ to 5500′ | 5500′ and over |
| Width of runways | | | | | |
| Day operation only | None | 100′ | | | |
| Day and night operation | " | 150′ | 150′ | 150′ | 150′ |
| Instrument landing | " | | 200′ | 200′ | 200′ |
| Percentage of time a runway should be available heading into wind[2] (Determines number and directions of landing strips and runways) | 70% | 75% | 80% | 90% | 90% |
| Minimum distance between center lines of parallel runways | None | 700′ | 700′ | 700′ | 700′ |
| Minimum distance between center line of runway and airport buildings—Instrument landing runway | | 750′ | 750′ | 750′ | 750′ |
| Minimum distance between runway center line and aprons and loading platforms—Instrument landing runway | | 500′ | 500′ | 500′ | 500′ |
| Distance between center line of runway and airport buildings—other runways | Desirable<br>Minimum | 500′<br>350′ | 500′<br>350′ | 500′<br>350′ | 500′<br>350′ |
| Minimum distance between center line of runway and aprons and loading platforms and parking areas—All other runways | | 250′ | 250′ | 250′ | 250′ |
| Maximum landing strip and runway grades[3]—Transverse | 2% | 2% | 1½% | 1½% | 1½% |
| Longitudinal | 2% | 1½% | 1½% | 1% | 1% |

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[1] All of the above landing strip and runway lengths are based on sea level conditions; for higher altitudes increases are necessary. One surfaced runway of dimensions shown above is recommended for each landing strip for airports in Classes 2, 3, 4 and 5.

[2] Landing strips and runways should be sufficient in number to permit take-offs and landings to be made within 22½° of the true direction for the percentage shown above of winds 4 miles per hour and over, based on at least a 10-year Weather Bureau wind record where possible. Negligible wind conditions of 3 miles per hour and under are classed as calms.

[3] In the development of initial units the grades should be established to conform with the standards for the ultimate development In special cases it may be necessary to exceed these maximums for economic reasons.

TABLE IV—Continued)

| Recommended Standards | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
|---|---|---|---|---|---|
| Grade changes[4]—longitudinal Maximum algebraic difference | 3% | 2½% | 2% | 2% | 2% |
| Minimum width of taxiways | — | 50′ | 50′ | 50′ | 50′ |
| Minimum distance between runway center line and parallel taxiway center line | — | 275′ | 275′ | 275′ | 275′ |
| Minimum distance from boundary fence, obstruction, etc., to taxiway center line | | 100′ | 150′ | 150′ | 200′ |
| Maximum longitudinal grade taxiway[5] | | 3% | 2½% | 2½% | 2½% |
| Maximum transverse grade taxiway | | 1½% | 1½% | 1½% | 1½% |
| Minimum angle of taxiway intersection with runway ends[6] | | 60% | 60% | 60% | 60% |
| Facilities required | Drainage<br>Fencing<br>Marking<br>Wind direction indicator<br>Hangar<br>Basic lighting (optional) | Same as Class 1 plus lighting<br>Hangar and Shop<br>Fueling<br>Weather information<br>Office space<br>Parking | Same as Class 2 plus Weather Bureau<br>Two-way radio<br>Visual traffic control<br>Instrument Approach System (when required)<br>Administration Building<br>Taxiways and Aprons | Same as Class 3 | Same as Class 4 |

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[4] Longitudinal intersecting grades on a runway or landing strip should be joined by a vertical curve if the algebraic difference in grade is 0.4% or more. The vertical curve should be at least 300 feet in length for each 1% change in grade. It is also recommended that the tangent interval between the point of tangency of one curve and the point of curvature of the succeeding curve be not less than 1000 feet. If economically practical, grade breaks should be so controlled that the sight line will be unobstructed from any point 10 feet above the surface of the runway to any other point 10 feet above the runway.

[5] Runway grades should not be altered to accommodate taxiway connections or intersections. At large airports where traffic is heavy it may be advisable to construct a warming-up apron and bypass on taxiways connecting to the ends of runways.

[6] Taxiways should not connect to the end of runways at an angle of less than 90° to incoming traffic.

Source: Airport Design, Civil Aeronautics Administration, April 1, 1944.

The C.A.A. has also published manuals of airport design and has issued technical reports on various subjects pertaining to aircraft performance, particularly with reference to runway requirements. The more pertinent of these publications are included in the Bibliography at the end of this paper.

The airlines have initiated airport design studies on their own behalf in order that they may have definite suggestions to offer whenever airport improvements on their system are under discussion. The unique tangential runway layout adopted for New York's new airport at Idlewild grew out of scheme advocated by the American Airlines, Inc. with the support of the other airlines serving New York.

## Runway Layout

A number of factors influence the airport runway pattern. Some of these factors have already been discussed. The most important is that of having a runway available at all times for takeoffs and landings into the wind, or very nearly into the wind. Another important consideration is the avoidance of obstructions, such as hills, tall buildings, towers or pole-lines in the approaches to the airport. The runway layout is also influenced at some sites by the nature of the terrain and the type of subsoil. Locations are preferred which require a minimum of excavation and embankment and which also provide a stable foundation for pavements. The shape of the airport site frequently controls the runway pattern, as the runways must be placed in the locations where land is available. The location of the terminal area and of adjacent highways and industries also has a bearing on the runway layout. Taxiing distances from the ends of the runways to the terminal apron should be as short as possible. Planes should be able to taxi to a takeoff and from a landing with a minimum of interference.

In view of the many and varied factors influencing the runway layout, it is not likely that a standard layout can be developed that will fit all sites. Some will be better than others. Objectional features, such as irregular and cramped sites with obstructions in the approaches, should be avoided as far as possible, by a wise selection of the airport site, as described above.

## Length of Runway

The length of runways should be such as to permit the safe landing and taking off of all types of aircraft that are expected to use the airport. The length required depends upon the performance characteristics of the airplanes to be served, particularly their takeoff and landing speed and their rate of climb. These characteristics are largely dependent upon the wingloading (gross weight divided by wing area) and power-loading (gross weight divided by takeoff horsepower) of airplanes. Table V shows the characteristics of a number of typical airplanes ranging in size from the 2-passenger Piper Cub

TABLE V—CHARACTERISTICS OF TYPICAL CIVIL AIRCRAFT

| *Make of Airplane* | *Piper Cub* | *Spartan Executive* | *Lockheed Saturn* | *Douglas DC-3* | *Martin 202* | *Douglas DC-4* | *Lockheed Constellation* | *Boeing Stratocruiser* | *Consolidated-Vultee Model 37* |
|---|---|---|---|---|---|---|---|---|---|
| Number of Seats | 2 | 4-5 | 16 | 21 | 30-42 | 44 | 48-64 | 76-100 | 204 |
| Dimensions | | | | | | | | | |
| Wing Span | 35'3" | 39' | 74' | 94' 7" | 92' 9" | 117' 6" | 123' | 141'3" | 230' |
| Overall Length | 22'3" | 26'10" | 51' 6" | 64' 5" | 71'11" | 93'11" | 95'1 3/16" | 110'4" | 182' |
| Height | 6'8" | 8' | 19'10" | 16'11" | 25' | 27' 7" | 23'7⅞" | 33'3" | 57' |
| Power Plant | | | | | | | | | |
| Engine Type | Continental | P&W[7] | Wright | P&W | P&W | P&W | Wright Cyclone | P&W | |
| Total Takeoff H.P.[1] | 65 | 450 | 1,050 | 2,400 | 4,200 | 5,400 | 8,800 | 12,000 | 30,000 |
| No. of Engines | 1 | 1 | 2 | 2 | 2 | 4 | 4 | 4 | 6 |
| Performance | | | | | | | | | |
| Max. Speed—m.p.h. | 87 | 212 | 240 | 230 | 306 | 280 | 350 | 400 | |
| Cruising Speed—m.p.h.[2] | 75 | 203 | 200 | 185 | 270 | 239 | 300 | 340 | 342 |
| Stalling Speed—m.p.h. | 38 | 65 | 72 | 67 | 80 | 80 | 80 | | |
| Rate of Climb—ft per min.[3] | 450 | 1,430 | 1,460 | 1,170 | 1,660 | 1,200 | | 2,000 | |
| Service Ceiling—ft.[4] | 11,500 | 24,000 | 26,000 | 24,100 | 29,800 | 29,200 | 35,000 | 30,000 | |
| Range—miles | 220 | 1,097 | 1,600 | 2,000 | 1,700 | 3,600 | 3,000 | 3,500 | |
| Weight—Pounds | | | | | | | | | |
| Gross Takeoff | 1,220 | 4,694 | 14,000 | 25,200 | 34,300 | 71,300 | 86,250 | 130,000 | 320,000 |
| Gross Landing | | | | | 33,100 | 56,500 | 75,000 | 105,000 | 235,000 |
| Empty | 740 | 2,846 | 9,634 | 18,865 | 23,324 | 38,000 | 52,000 | 69,600 | 164,100 |
| Wing Loading[5] | 6.8 | 17.6 | 37.9 | 25.5 | 39.8 | 48.9 | 52.3 | 74.3 | 67.2 |
| Power Loading[6] | 18.8 | 11.0 | 11.7 | 10.5 | 8.2 | 13.3 | 9.8 | 10.8 | 10.7 |

[1] For all engines. [2] Varies with altitude. [3] At sea level—decreases with altitude. [4] Altitude at which rate of climb drops to 100 ft. per min. [5] Pounds per sq. ft. of wing area based on take-off gross weight. [6] Pounds per take-off H.P. based on gross take-off weight. [7] Pratt & Whitney.

to the proposed Leviathan of the air, the 320,000-pound Consolidated-Vultee Model 37.

The C.A.A. has suggested a rough rule that the runway length should be 15 times the product of wing loading and power loading. This rule appears to give fairly acceptable lengths for airplanes of the DC-3 (25,200 pounds) size and smaller, but does not apply to larger planes. (See Table VI.) A more scientific method for determining runway length is available in the Civil Air Regulations,* which prescribe runway length in terms of the actual performance characteristics of airplanes. These regulations were devised primarily to determine the relation between gross weight of transport airplanes and safe runway length required under various operating conditions. They also provide a means for determining the runway length necessary to allow the full utilization of the rated gross weight of the airplane, as certified by the C.A.A.

Three criteria have been set up for runway lengths: two for takeoff and one for landing. The regulations prescribe in technical terms the exact condition to be met. In brief, non-technical language, the most exacting of the three following requirements must be met.

(1) The length shall be sufficient to permit the airplane to be accelerated to the verge of takeoff and then, in the event of failure of one engine, be braked and brought to a stop within the length of the runway.

(2) The length shall be such as to permit the airplane to be accelerated to the verge of takeoff and then, in the event of failure of one engine, be able to continue and climb at such a rate that the boundary of the landing strip (and the objects beyond) are cleared by a minimum height of 50 feet.

(3) The length for landing shall be such that the airplane can glide into the airport from a height of 50 feet above the end of the landing strip, land upon the runway and be brought to a stop within 60 per cent of the runway length.

Fig. 3 illustrates takeoff requirements. The plane is accelerated in the takeoff position with all engines operating at takeoff horsepower (10 to 20 per cent higher than rated horsepower) and loaded to the maximum gross weight certified by C.A.A. An engine is then assumed to fail at the "critical engine failure point" which occurs when the air

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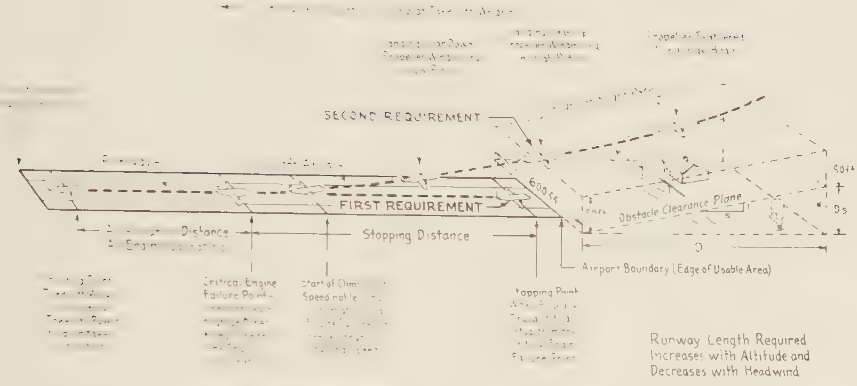
*Civil Air Regulations, Part 04, Airplane Worthiness, Sec. 04.75, Performance Requirements for Transport Category Airplanes.



Runway Length Required
Increases with Altitude and
Decreases with Headwind

FIG. 3.

speed of the plane is at least equal to that at which the airplane is controllable with only the remaining (1 or 3) engines operating. To satisfy the first requirement, all engines are cut at the critical engine failure point and the plane braked to a stop on the runway. To meet the second requirement, the plane continues from the engine failure point with the remaining (1 or 3) engines at takeoff power until a speed equal to 1.10 the speed at engine failure has been reached (or 1.15 the stall speed whichever is greater) and then takes off and climbs clearing the end of the usable landing area (and all obstacles beyond) by 50 feet. As the climb proceeds the landing gear is retracted and the propeller of the dead engine is feathered; i.e., the pitch or angle of the blades is adjusted so that they do not rotate. When the plane gains sufficient altitude it will turn, circle the field and land. The stall speed, referred to above, is that speed at which the flow of the air over the wings becomes turbulent. When this happens, the lift on the wings is greatly reduced and the airplane is likely to crash if near the ground.

The landing requirement is illustrated in Fig. 4. The airplane must clear all obstacles in the approach zone by 50 ft., cross the boundary of the usable landing strip at a height of at least 50 ft., descend to the runway, decelerate and stop within 60 per cent of the runway length.

Usually the second requirement for takeoff is controlling. The actual dimensions and slope of the takeoff (or landing) path may be

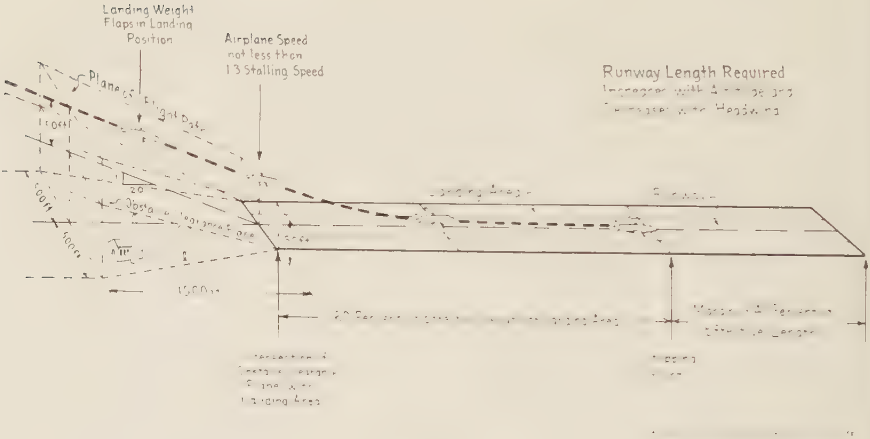


FIG. 4.

figured mathematically from the performance characteristics of the airplane, or they may be determined by photographic records of the actual performance of airplanes. The C.A.A. is accumulating information of this sort.* The runway lengths required to meet the C.A.A. regulations are shown in Table VI for a number of air transports. Some of these planes are in service; others still in the development stage. The runway lengths are at sea level. They are longer for greater altitudes as shown in Fig. 5 and discussed below.

## EFFECT OF AIRCRAFT DESIGN ON RUNWAY LENGTH

An understanding of the relation between runway length and airplane performance may be had from an examination of the basic formula for lift on the wings of an airplane:

$$L = C_L \frac{\rho}{2} S V^2 \tag{1}$$

in which $L$ = lift on wings in pounds.

$C_L$ = lift coefficient which depends upon the shape of the wing and its inclination with the direction of flight (angle of attack).

$\rho$ = mass density of air in slugs per cu. ft.

$S$ = area of wings in sq. ft.

$V$ = air speed in ft. per sec.

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*The Correlation of Aircraft Take-off and Landing Characteristics with Airport Size, Technical Development Report No. 40, April 1944, Civil Aeronautics Administration.

TABLE VI—RUNWAY LENGTH REQUIRED TO MEET CIVIL AIR REGULATIONS FOR TYPICAL TRANSPORT AIRPLANES AT SEA LEVEL—NO WIND

| *Make of plane* | *For Takeoff* Gross Weight (Lbs.) | Runway Length (Ft.) | *In Landing* Gross Weight (Lbs.) | Runway Length (Ft.) | *Wing Loading Times Power Loading* | *Ratio Max. Runway Length to (WL × PL)* |
|---|---|---|---|---|---|---|
| | | | *Two-Engine* | | | |
| Douglas DC-3 | 25,200 | 3,950 | 24,400 | 3,310 | 268 | 14.7 |
| Curtiss-Wright CW-20E | 48,000 | 5,100 | 46,400 | 3,700 | 353 | 14.4 |
| Martin 202* | 34,300 | 3,750 | 33,100 | 3,500 | 326 | 11.5 |
| Fairchild Packet | 45,000 | 3,600 | 45,000 | 3,740 | 345 | 10.8 |
| Douglas DC-8* | 39,500 | 3,950 | 39,500 | 3,960 | 433 | 9.2 |
| | | | *Four-Engine* | | | |
| Douglas DC-4 | 68,000 | 5,100 | 58,200 | 4,520 | 586 | 8.7 |
| Douglas DC-6 | 80,500 | 4,200 | 63,500 | 4,850 | 538 | 9.0 |
| Constellation | 90,000 | 4,000 | 77,800 | 4,000 | 552 | 7.3 |
| Douglas DC-7 | 162,000 | 6,640 | 127,500 | 5,200 | 870 | 7.6 |

Note Runway requirements for DC-4 and Constellation were obtained from the Civil Aeronautics Administration. Other data were taken from Company specifications.

*Transports still in development stage.

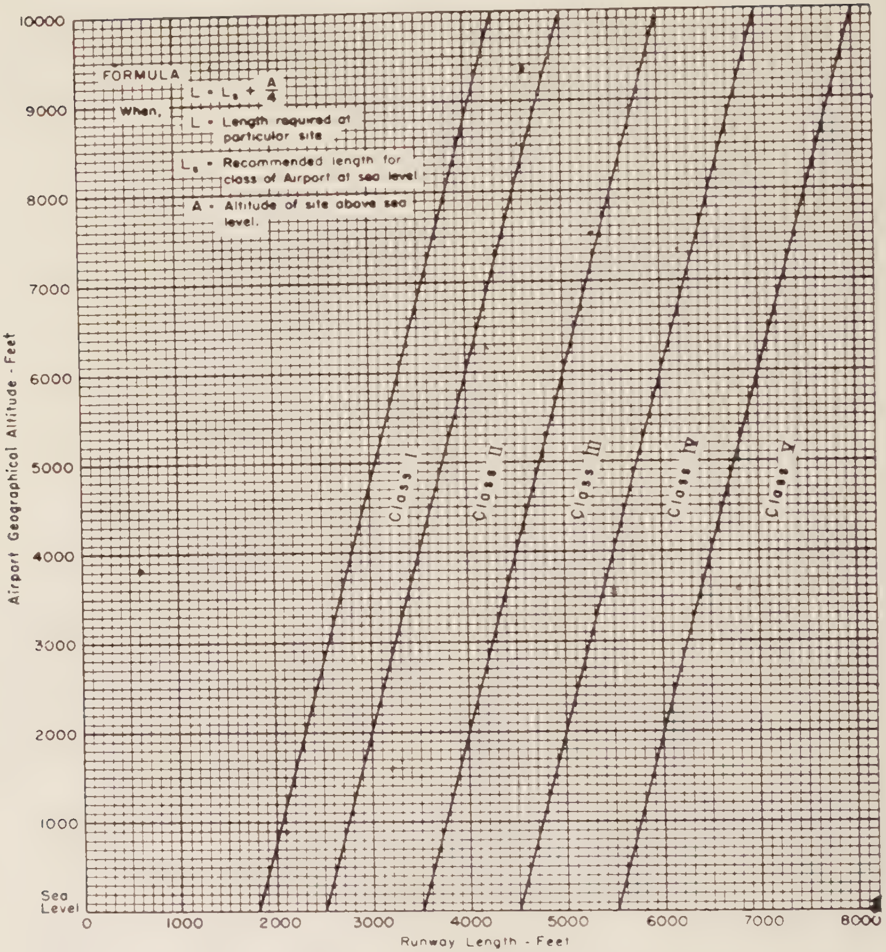

FIG. 5.—EFFECT OF ALTITUDE ABOVE SEA LEVEL ON REQUIRED RUNWAY LENGTH.
*From "Airport Design", C. A. A. 1944.*

In order to take off and sustain flight, $L$ must be at least equal to $W$, the weight of the airplane,

$$L = W = C_L \frac{\rho}{2} S V^2 \qquad (2)$$

From this formula it will be seen that as the density $\rho$ decreases, as it does with altitude or with an increase of temperature or reduction in pressure, the decrease must be made up by an increase in speed, since $C_L$ at takeoff and $S$ are practically constant for a given airplane. Higher takeoff speeds mean longer takeoff runs and therefore longer runways.

Since $V$ is the air speed, headwinds add to the ground speed and increases the lift. Hence the takeoff may be accomplished in a shorter run against a headwind than in still air. Similarly in landing a headwind increases $V$ and allows a lower landing speed relative to ground and therefore a shorter roll to a stop than is required when there is no wind.

When formula (2) is rearranged to represent wing loading, it becomes:

$$\frac{W}{S} = C_L \frac{\rho}{2} V^2 \tag{3}$$

From this it will be seen that an increase in $W/S$ with $C_L$ and $\frac{\rho}{2}$ constant must be balanced by an increase in $V$ with an accompanying demand for longer runways. In recent years the trend in airplane design has been toward higher and higher wing loadings in the larger models as indicated in Table V, and shown graphically in Fig. 6.

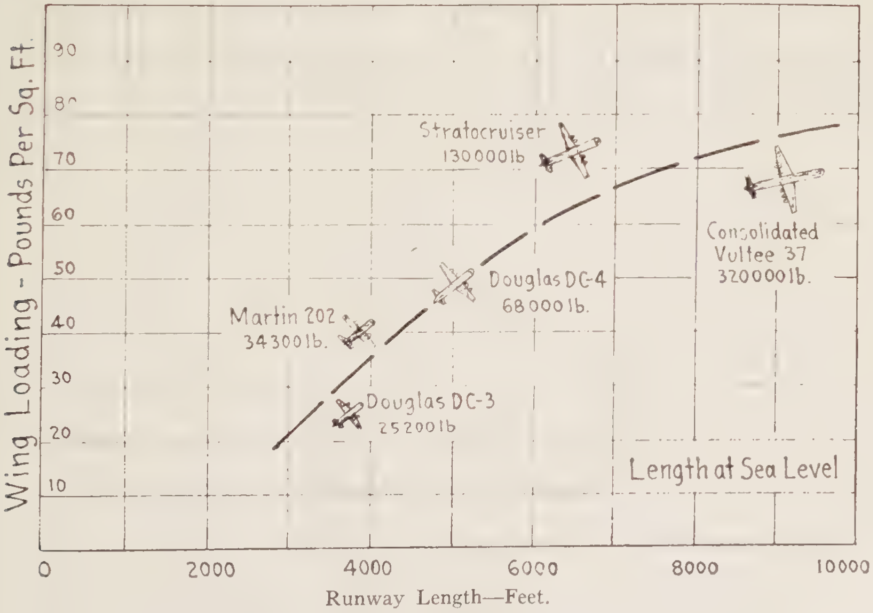

Fig. 6.—Wing Loading vs. Length Prescribed by Civil Air Regulations.

Improvements in design have brought some increase in $C_L$, but for the most part the higher wing loadings have been accompanied by increases in landing and takeoff speeds. The plotted positions of the larger transports are approximate only, since these planes have not yet been rated for commercial use. An increase in power either from more powerful engines or by assisted takeoff devices could shorten the runway requirements for these larger planes. Increasing their gross weight, on the other hand, could increase their runway length requirements.

Another factor influencing runway length is power loading (gross weight divided by total horsepower). Generally speaking, the more pounds to be lifted per horsepower the longer will be the takeoff run and the flatter the takeoff path in climbing out of the airport. The trend in power loading, however, has been downward in recent models, but the change has been small compared with the great increase in wing loading, as indicated in Table V.

In order to meet runway length requirements, airport sites have had to be enlarged and, in some instances, abandoned in favor of new sites. Grading, drainage and pavement costs have soared. Ultimately, some limit, economic or operational, may be reached in runway length and airport size. Radical changes in aircraft design, such as the universal use of assisted takeoff devices coupled with braking by reversible pitch propellers or other retarding devices, give promise of shifting some of the responsibility for meeting takeoff and landing requirements from the airport designer to the aircraft designer. In the immediate future, long runways appear in demand, but radical improvements in aircraft takeoff and landing abilities could remove the necessity for huge airports.

## Effect of Wind on Runway Length

There will usually be one principal runway at each airport that is used during calms and at times of low wind velocity. This runway should be of sufficient length to meet landing and takeoff requirements in still air at the geographic elevation of the airport. It is also desirable that the principal runway be laid out in the direction of the most prevalent winds of high velocity, thus being available for heading into these winds and avoiding high cross winds. Other runways presumably will only be used when the allowable cross wind component (at right angles to the main runway) is exceeded. This means that when another runway is used there will be a headwind component along that runway which will shorten the landing and takeoff run. Hence it is not so important that the minor runways be as long as the principal runway. The allowable cross wind varies for different airplanes. Generally speaking, it is less for light planes than for the heavy transports with tricycle landing gears. For commercial transport operation a cross wind component of 10 m.p.h. is very conservative, and 15 m.p.h. is probably permissible. For the heavier transports, possibly 20 m.p.h. may be permitted. If we assume that the major runway will be used until the permissible cross wind component is reached, then it is possible to compute the headwind component that will be available on the minor or "cross" runways. The relation is illustrated in Fig. 7.

If, for example, the allowable cross wind component on the main runway *A-A* is 15 m.p.h., and the wind is blowing along the bisector of the angle between runways *AA* and *CC* ($\alpha = \beta$), and fur-

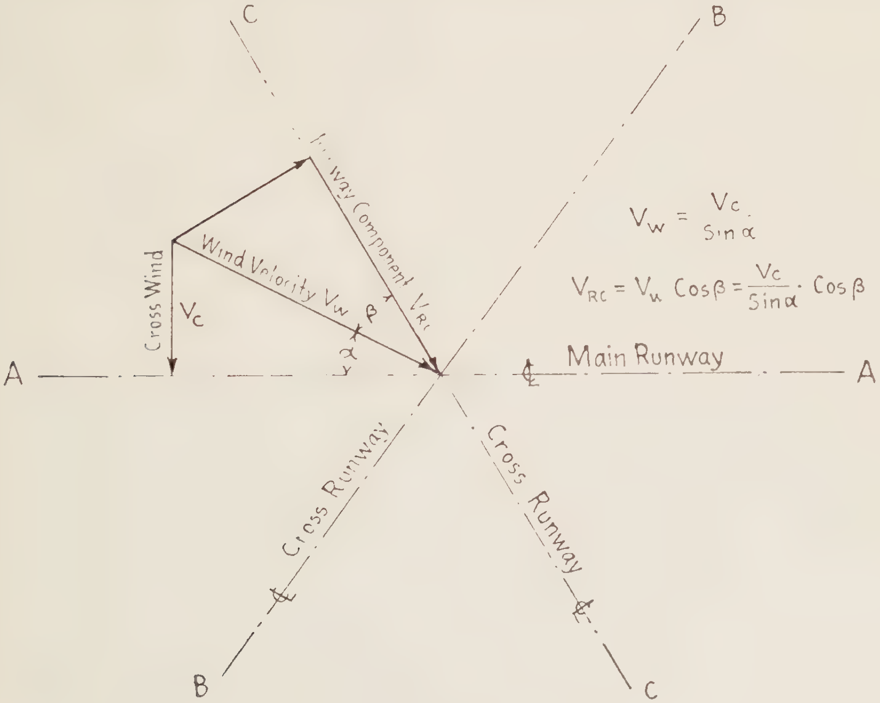

Fig. 7.

ther assuming that the angle *COA* between runways is 60 degrees, then the head wind component along runway *CC* is $V_{CR} = \frac{15}{.5} \times .866 =$ 26 m.p.h. The Civil Air Regulations suggest that one-half of this headwind component may be taken into account in computing the length of landing (or takeoff) run. The chart in Fig. 8, prepared by the C.A.A., shows the decrease in runway length that may be allowed at different altitudes for different headwinds. These curves have been prepared on the basis of the types of planes that will use class 4 airports. If a headwind of 26 ÷ 2 = 13 m.p.h. is used in design, the reduction factor is .78 at sea level and .80 at 10,000 elevation. This means that if the main runway is 5000 feet long and at sea level, a cross runway at 60° (as in the above illustration) may be 5000 × .78 = 3900 feet long and still permit as safe takeoff and landing performance as on the main runway in still air.

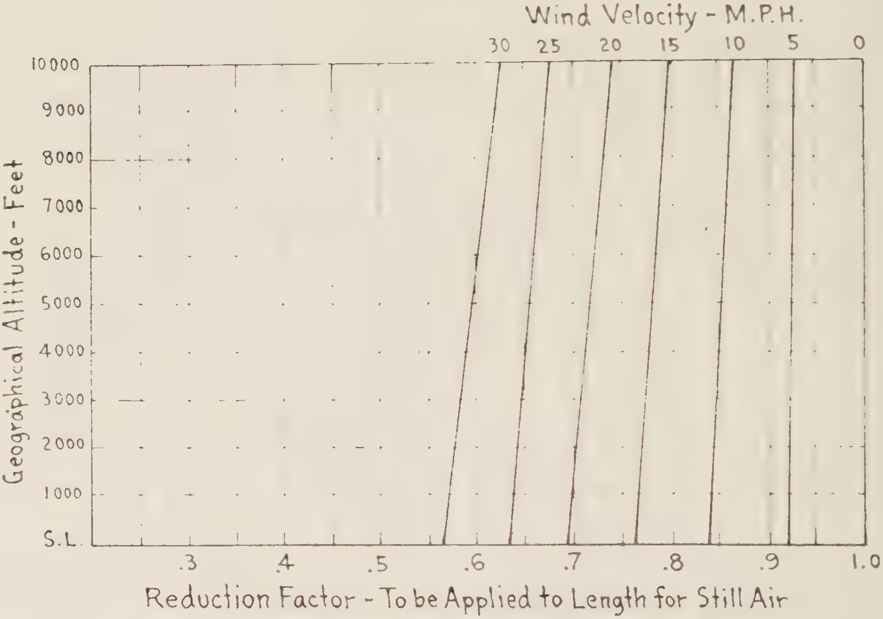

FIG. 8.

A headwind not only shortens the runway length required but also steepens the angle of climb and the slope of the obstacle clearance

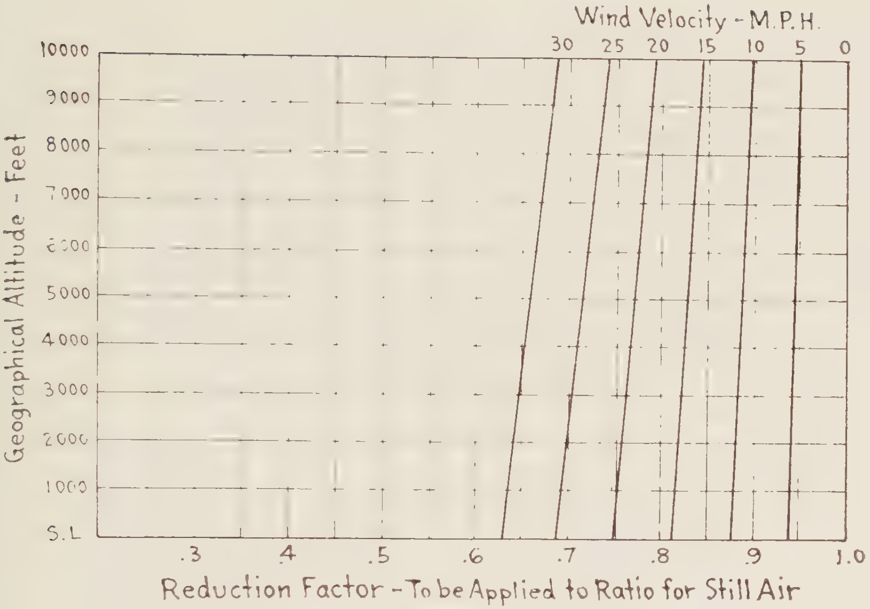

FIG. 9.

line. The reduction possible is shown for various headwinds and at different altitudes in Fig. 9. For example, if the obstacle clearance zone is designed for a slope of 1 in 40 at sea level in still air, the slope may be increased (the ratio decreased) to .84 of the ratio at sea level; i.e., for a headwind allowance of 13 m.p.h. a slope of 1 in34 is equivalent to 1 to 40 in still air.

## NUMBER OF RUNWAYS

The usual runway layout has two, three or four runways in as many different compass directions. The number of runways is determined largely by the per cent of wind to be covered. The C.A.A. standards specify that each runway may be considered to cover a 45° sector lying 22½° on each side of the centerline.

Although cross winds are a more serious hazard to light planes than to heavy planes, the smaller airports for light planes are, for the sake of economy in construction, usually laid out with only two runways, and are required by the C.A.A. specifications to cover only 70 per cent of the wind. In some localities the wind blows predominantly in one direction or the opposite, and one runway will suffice, but in localities where the wind may blow from any direction, as in most of the United States, three or four runways are required to meet the C.A.A. specification of 90 per cent wind coverage for class 3 and larger airports. If the prescription that each runway direction covers 45° of arc is strictly adhered to, four runways are needed for most locations. If, however, the limit is raised to 60° for the larger planes with tricycle landing gear, wind conditions can be satisfied with three runways at most sites. The present trend is toward three long runways with good approaches in preference to four shorter ones with less desirable approaches.

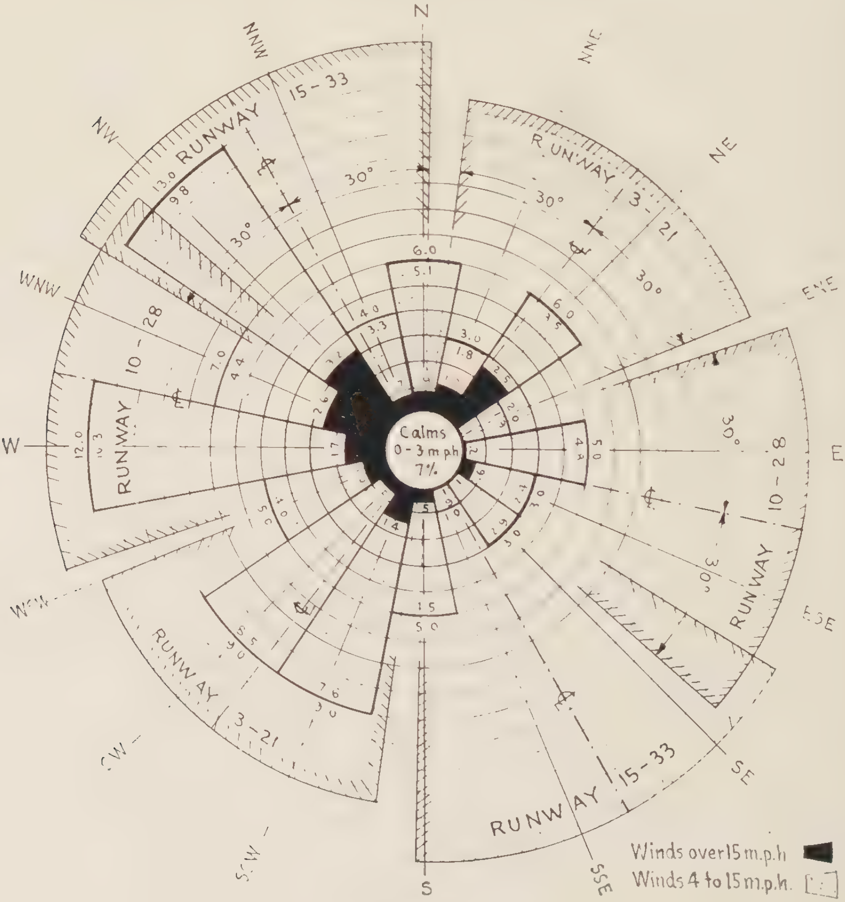

FIG. 10.

## Wind Rose

In order to select the best orientation of the runways to cover winds, use is made of a diagram called a wind rose. The usual form is a series of bands radiating in the several compass directions and varying in length according to the percentage of time that the wind blows from each direction. Such a wind rose is shown in the upper left corner of Fig. 2. A more detailed plot of this same wind rose is shown in Fig. 10 in which the percentages are plotted as sectors of varying radius instead of as bands. The small circle in the center represents calms (winds of 3 m.p.h. or less) during which any runway could be used. The dark sectors represent winds over 15 m.p.h. and the open portions of the sectors represent winds of from 4 to 15 m.p.h.*

Superimposed on the wind rose are 60 -sections (cross hatched) which represent the portions of the wind rose "covered" by the three runways shown in Fig. 2. An inspection of the diagram shows that there are four "gaps" where the winds are not covered by the 60°-sectors. The percentage of wind represented by the gaps is computed as follows:

| | *Total Winds* | *Winds over 15 m.p.h.* |
|---|---|---|
| Near N | .3 × 6% = 1.8% | .3 × .9% = .27% |
| Near S | .3 × 5 = 1.5 | .3 × .5 = .15 |
| Near ENE | .2 × 2 = 0.4 | .2 × .1 = .02 |
| Near WSW | .2 × 5 = 1.0 | .2 × 1.0 = .20 |
| | 4.7% | .64% |
| All Winds | 100.0% | 3.70% |
| Per Cent Covered | 95.3% | 96.3% |

If the wind coverage had been limited to 22½° each side of the centerline of each runway, as recommended by the C.A.A., the coverage would have been 80.2 per cent for all winds and 81.9 per cent for winds over 15 m.p.h. What is important in this problem, however, is the allowable cross wind rather than the angle of coverage. A cross wind component of 15 m.p.h. will result from a wind of 30 m.p.h. at 30° with the runway and a wind of 39 m.p.h. at 22½°. At the site where the wind rose of Fig. 10 was taken winds over 30 m.p.h. blew less than 1 per cent of the time.

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*This type of wind rose is described in "Runway Orientation in Terms of Aircraft Take-off and Landing Characteristics" by Thomas E. Greacen, II, in Aeronautical Engineering Review, February 1946.

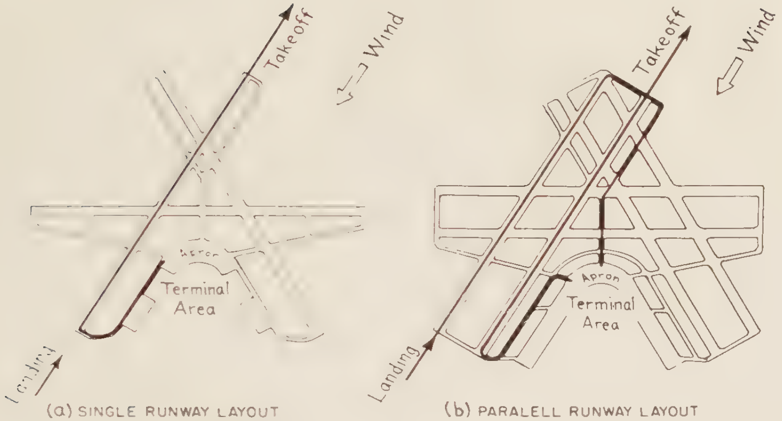
## Parallel Runways

The capacity of an airport with a single runway in each direction (Fig. 11a) is from 40 to 60 landings plus takeoffs per hour. When the traffic demands on an airport exceed the capacity of a single-runway layout, the capacity may be approximately doubled by providing two pairs of runways in each wind direction, as indicated in Fig. 11b. With parallel runways, landings may be made on one of the parallel runways while takeoffs are being made on the other, the maximum rate being 80 to 100 plane movements per hour for both runways. The standards in Table V call for a minimum spacing of 700 feet between parallel runways; they may, however, be much farther apart, and will operate more efficiently if widely separated, since traffic interference both on the ground and in the air approaches is reduced. Some designs call for parallel runways several thousand feet apart with the air terminal in between (Figs. 11c and 12).

## Tangential Runway Layout

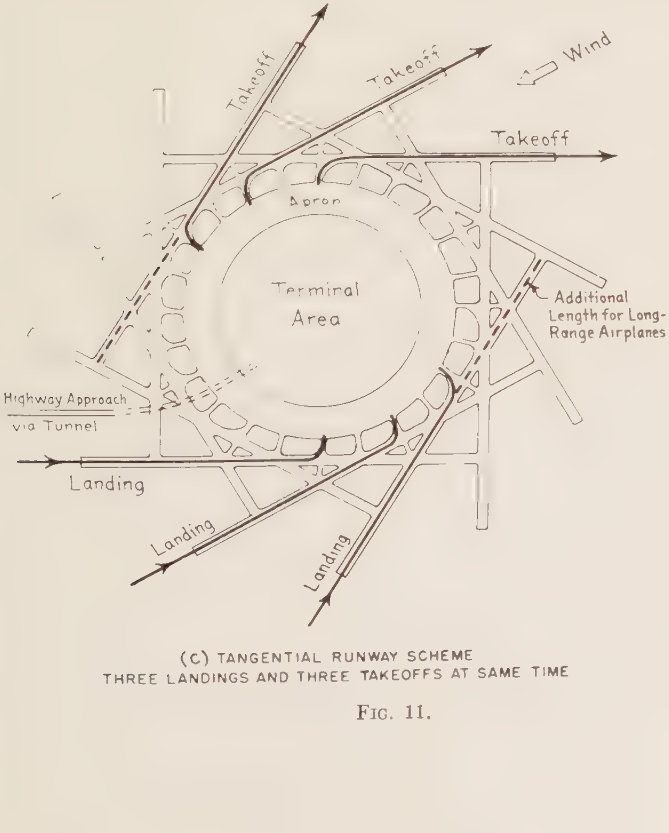
When the traffic potential exceeds that of parallel runways, a tangential system has been devised as illustrated in Fig. 11c which will permit 3 landings and 3 takeoffs simultaneously. The layout also has the advantage that all runways adjoin the central apron thus reducing taxiing distances. Normally only one-half of the total runway length is needed as shown by the full heavy lines indicating landings and takeoffs. For long-range flights with the larger planes, the full length of the runway may be utilized as indicated by the dashed lines in Fig. 11c. The disadvantage of the tangential laycut is the large site required and the necessity for highway approaches via a vehicular tunnel.

A modification of the tangential scheme was adopted for the ultimate layout of the Idlewild Airport under construction for New York City. This layout, illustrated in Fig. 12, will be built in three stages. When fully developed, the airport is expected to handle a maximum of 360 airplane movements per hour in clear weather; 60 landings on each of 3 runways and 60 takeoffs on 3 other runways on the opposite side of the airport. As the wind direction changes, different sets of runways will be used. There will always be six runways available, no one of which makes an angle of more than 30° with the prevailing wind direction.



(a) SINGLE RUNWAY LAYOUT
ONE LANDING OR ONE TAKEOFF AT A TIME

(b) PARALELL RUNWAY LAYOUT
ONE LANDING AND ONE TAKEOFF AT SAME TIME


Takeoff
Takeoff
Wind
Takeoff
Apron
Terminal Area
Additional Length for Long-Range Airplanes
Highway Approach via Tunnel
Landing
Landing
Landing

(c) TANGENTIAL RUNWAY SCHEME
THREE LANDINGS AND THREE TAKEOFFS AT SAME TIME

FIG. 11.

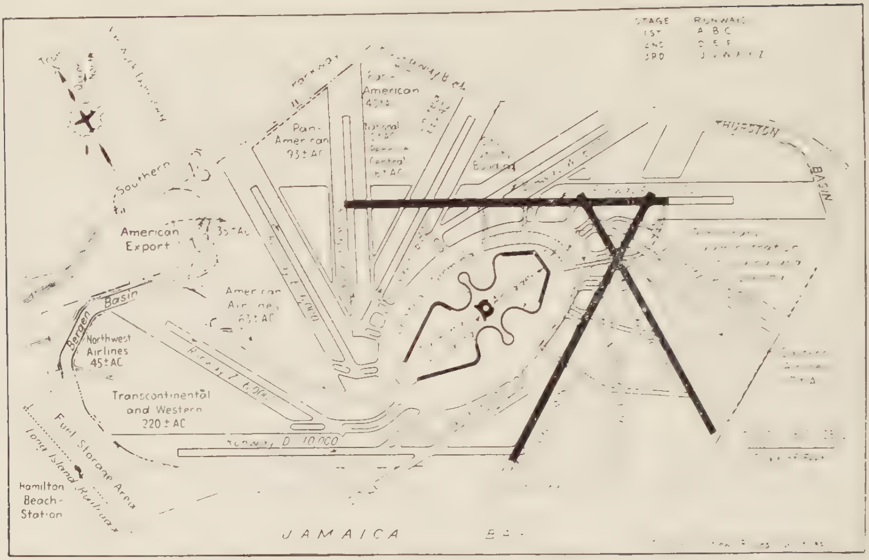


Fig. 12.—Layout of Idlewild, New York, Airport.

In overcast weather, when the pilot must rely on his instruments and radio, landing procedure is slow and the capacity of the airport is greatly reduced. Improvements in air traffic control and the general adaptation of blind landing systems are expected to speed up landing procedure and overcome much of the loss of capacity now experienced in bad weather.

## Taxiway Systems

The purpose of the taxiway system is to allow airplanes to move from the terminal to the takeoff position in a direct path without interfering with the loading and unloading of other planes and without interfering with the landing and takeoff of other planes. Similarly landing planes should be able to turn off the runway soon after they have come to a stop (or to taxiing speed) and be able to proceed directly to the terminal without interfering with movements of other planes. In the usual layout only one runway is used at a time (Fig. 11a). The unused runways may serve as taxiways, if conveniently located, but usually especially designed taxiways are necessary for good circulation. The field must be studied for operation on each runway separately. If any preference must be given in the provision of taxiways, the most-used runway should be the most accessible to the terminal.

Provision must also be made for taxiing between hangars and the terminal, and from the field directly to the hangars in order to accommodate planes that do not have to go to the terminal. In the illustrations (Figs. 11 and 12) taxiways are indicated by the closely spaced parallel lines connecting the runways and aprons.

## Apron or Ramp

The apron or ramp is the wide paved area adjacent to the terminal and usually extending in front of the hangars. It is used for loading, unloading and parking of planes, and also for taxiing. The dimensions and shape of the apron depend upon the number and size of airplanes to be accommodated, as will be discussed below under Terminals.

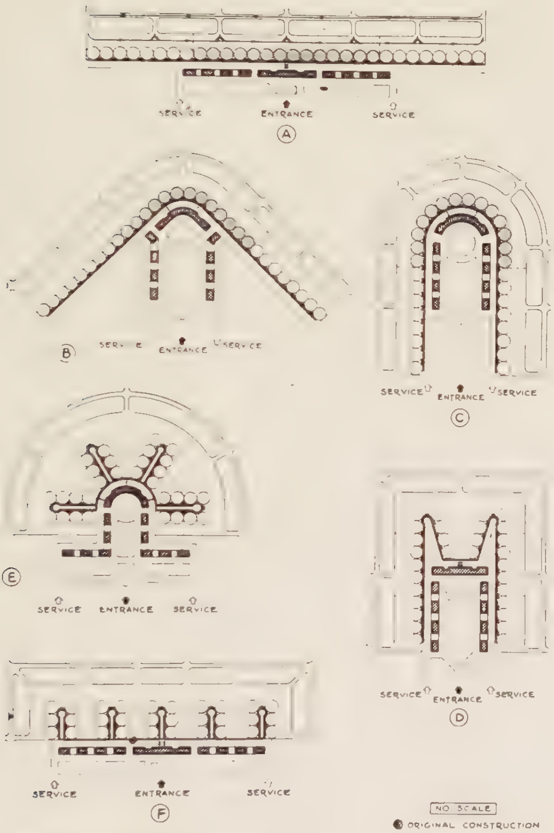
## The Terminal

In the past terminals at commercial airports have frequently been built too small and of such permanent construction that expansion has been difficult. Designers have been shortsighted in providing for air transport growth and in visualizing the airport terminal's function. The terminal layout should provide for a smooth flow of surface traffic to and from the airport terminal and adjacent hangars and service buildings, with ample parking space for both patrons and workers. Direct access to waiting planes is desirable for passengers who have purchased tickets in advance. For others, and for those waiting for plane connections, an attractive and commodious waiting room is required, conveniently located with respect to ticket offices and public conveniences. Mail and express must be transferred from truck to plane, usually at a lower level, where it will not come in contact with passengers. Space is also required for airlines' offices, the airport manager, traffic control and weather bureau staff and equipment. Provision should be made for handling spectators in such a way that they may view the activities of the airport without interfering with airport activities or mixing with passengers. Concessions catering to patrons and the public, such as restaurant, barber shop, haberdashery, soda bar, and souvenir counter, should be encouraged as added attractions to the airport and sources of airport revenue.

At present airplanes are unloaded, loaded and serviced on the apron adjacent to the air terminal building. A fleet of small vehicles, some motorized and some pushed by hand, are used to bring mail, express and supplies to and from the airplane. This process, employing much hand labor, may be but a passing phase. As air traffic grows, mass transportation methods may evolve which are difficult to foresee. Mail and express will probably continue to be carried in the same airplanes as passengers, and will therefore have to be handled at the airline station. Air freight will move to an increasing extent in separate, all-cargo transports, that may be better served at another part of the airport, or at a separate airport.

The airport terminal differs greatly from a railroad terminal in the spacing of the gates required for a loading and unloading passengers. A frontage of about 20 feet at a rail terminal will accommodate a track and platform that can serve a train of several hundred passengers. An inspection of the wing spans of transports in Table V indicates that each plane requires from 100 to 175 feet of frontage at the airport terminal in order to handle planes of 20- to 60-passenger capacity.

If each plane is allowed 30 minutes at the terminal, 10 berths will be required to match the capacity of a single runway at 40 movements per hour. If each plane is allotted a circle of 150-foot diameter, the frontage (or apron) will be 1500 feet long. If 360 plane movements per hour are to be served, as planned for New York's airport at Idlewild, 90 berths will be required, which, at 150-foot intervals, would extend 13,500 feet or 2½ miles. Actually an apron 1200 feet long is contemplated at Idlewild. In order to provide long frontages without exceeding a reasonable walking distance from a central terminal building, the straight apron in front of the terminal (Fig. 13A) has been abandoned in favor of curved or nose-shaped aprons (Fig. 13 B and C) running along three sides of the building location. In some designs the terminal area has approached a circular shape, and in others the perimeter has assumed an indented or scalloped shape (Fig. 12) in order to give a maximum frontage with a minimum internal area. Another device used to increase the number of berths is a projection or "finger" protruding on to the apron. The use of fingers concentrates the planes in front of the terminal but makes access to the berths by planes more difficult (Fig. 13 D, E and F).



**APRON LAYOUTS** – From "Airport Buildings", C.A.A.

FIG. 13.

As the airport terminal area increases in size, one central terminal building becomes less effective as a passenger station. Current thought is turning toward separate terminals for each airline located adjacent to each airline's berth. This arrangement is convenient for patrons who have made reservations with a particular airline, as is now usually the case. Such a system of single terminals, however, tends to perpetuate the individualistic policies of the airlines in carrying on complete terminal operations independent of one another. After a period of individualism, the railroads found it to their mutual advantage to organize subsidiary terminal companies to handle their joint terminal functions. As air transport approaches the mass transportation stage, the airlines may find terminal companies advantageous. The ground handling costs of the airlines are relatively high, and economies in this field appear possible as well as in aircraft operation, which at present is being given major attention. An airline terminal company could, under contract with the city, take over the management of the airport concessions and exploit revenues from this source to help support the airport. It might also provide ground transportation to the city. In the long run, the central terminal idea with intra-airport transportation may offer a solution to the problem of excessive distances.

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# OF GENERAL INTEREST

## MEETING OF BOARD OF GOVERNMENT

The Board of Government held a regular meeting on May 21, 1947. In addition to the usual routine business of electing members, checking the finances of the society etc., the following business of general interest was transacted.

Prof. Albert Haertlein, Chairman of the Committee on 100th Anniversary was a guest at the meeting and presented the following report.

BOARD OF GOVERNMENT
BOSTON SOCIETY OF CIVIL ENGINEERS
DEAR SIRS:

The Special Committee on the Celebration of the 100th Anniversary has considered the suggestions made by the Board on April 8, 1947.

The Board did not state whether monies have been appropriated for the conduct of the celebration. If the celebration is to be self-supporting, that is the price of the banquet or dinner-dance to cover all expenses, it would be necessary to limit the special guests to comparatively few so as not to discourage members from participating.

Your committee does not approve of favors commemorating the occasion. It would rather spend money for a special issue of the Journal or perhaps an entirely separate publication commemorating the contributions of members of the Society in the advancement of the art and science of civil engineering during the past hundred years or an outlook into the future of civil engineering. In order to have such a publication nicely printed on quality paper and special binding, the committee estimates the cost to be between one and two dollars per copy. It would be desirable to have such a publication free from all advertising. Does the Board approve such a publication and make the necessary appropriation?

The Committee also recommends that the celebration take the form of a dinner-dance and be held at an adjourned meeting of the annual meeting not later than April first. The scheduled date for the annual meeting is Wednesday, March 17. At this meeting all business, including the presidential address and the award of prizes, could be transacted. To hold the dinner on the same evening would not afford the opportunity for members to escort their ladies to the dinner. It should also be noted that accommodations for holding a dinner-dance on the evening of March 17, 1948, are not readily obtained at this date. For example, the Statler Hotel is not available.

The Committee seeks instruction from the Board on the following matters:

1. Appropriation for the 100th Anniversary Meeting.
2. Whether or not advertisements should be included in the special publication and an appropriation for its publication.
3. Banquet with several speakers or dinner-dance with one principal speaker.
4. Banquet or dinner dance later than March 17 but prior to April 1, 1948.

Respectfully submitted for the Committee on the 100th Anniversary Celebration.

JOHN B. BABCOCK
FRANK A. BARBOUR
CARROLL A. FARWELL
WILLIAM F. UHL
ALBERT HAERTLEIN, *Chairman*
May 13, 1947

Following considerable discussion the following verbal instructions were given Prof. Haertlein for the Commttee:—

1. That a commemorative publication was desirable and that unless it could not be avoided that it should carry no advertising.
2. That the committee prepare a budget and present it at a special meeting of the Board to be held in June.
3. That the Board favored a dinner-dance to be held on a separate evening from the Annual Meeting.

At the meeting of the Board in April it was voted that there was an excess of earnings available in the Herschel Fund, and the Secretary was instructed to determine what limitations were connected with this money. The Secretary reported that he could find no stipulations regarding the use of the income of this fund. By usage the income is now used to purchase books for the Herschel Prize Awards. It was voted "That excess income of the Herschel Fund not required for the purchase of prizes be used from time to time for the benefit of the Society and its members".

Prof. Donald W. Taylor, Chairman of the Committee on Subsoils of Boston, presented the following report:—

BOARD OF GOVERNMENT
BOSTON SOCIETY OF CIVIL ENGINEERS
GENTLEMEN:

In compliance with the recent directive of the Board of Government, the Committee on Subsoils presents its recommendations and its proposed program as follows:

The two main subjects that the committee has discussed, and on which it is hoping to obtain and possibly publish data in the near future, are groundwater conditions and boring records.

The collection of data from test borings has been the main objective of the committee in the past and continuation of this work is believed to be the most important contribution the committee can make in the future.

The committee is in hearty accord with a suggestion made by the President of the Society, that a paper on groundwater investigations be solicited from some representative of the U. S. Geological Survey for presentation at a meeting of the Society. The committee recommends that the representative of the Geological Survey also be asked to submit his paper for publication and that he be requested to include a digest of the data that have been obtained in recent investigations, particularly in the investigations conducted in the vicinity of greater Boston. The committee accepts as one of its main functions the task of aiding in making this type of data available to members of the Society and to the profession and believes that an authoritative paper of this type is a good method of accomplishing this objective.

The committee also wishes to call attention to the large volume of boring data for Boston and surrounding localities that was obtained between 1931 and 1939 and that is now available in a card index and on 14 maps at the Society rooms. These data are used fairly frequently, but they would be more widely used if better known, and if in readily available form. If it is the desire of the Board to publish these data, it is suggested that the material can be divided into about five sections, each section consisting of maps and approximately 100 pages of data. For the first section the Boston peninsula is suggested aid by adding to the existing maps only data that are readily available, the committee estimates that this section can be ready for publication by early in 1948. Once the preparation of the first section has been started, the work of bringing maps for the other sections up-to-date can be planned. If one section is published each year, all of the material will be made available within a reasonable time.

Expenses in addition to the cost of publication would consist mainly of secretarial work, which the committee estimates would come to $150 to $200 per section. It is believed that all other work can be cared for by the committee.

Since a publication of this type cannot be complete, it is suggested that each section be announced several months in advance with invitation to all engineers to contribute additional data. This procedure would minimize criticism relative to incompleteness.

It is possible that all sections could later be reprinted in book form. Book form for the original publication of the material is not recommended because the preparation of such a book would require considerable time.

Respectfully submitted,
Miles N. Clair
Irving B. Crosby
Stanley M. Dore
Lawrence G. Ropes
Donald W. Taylor, *Chairman*
May 19, 1947

It was voted "That the report of the Committee on Subsoils be accepted and that the Committee be authorized to proceed with its recommendations. The sum of $150 from the income of the Herschel Fund is made available to start this work".

Upon recommendation of the Library Committee the following votes were made:—

"That all copies of the periodical *Power* from 1916-1940 and of *Iron Age,* from 1920-1940 be donated to the Library of Northeastern University.

"That the following periodicals be donated to the Library of Georgia School of Technology":

| | |
|---|---|
| American Society of Municipal Improvements | 1901-1932 |
| Concrete | 1914-1939 |
| Enginering and Contracting | 1908-1930 |
| Engineering and Mining Journal | 1875-1878<br>1893-1902<br>1921-1932 |
| Journal of Municipal Engineers | 1916-1921 |
| Proceedings of Western Soc. of Engineers | 1880-1881 |
| Proceedings of Eng. Society of Western Penn. | 1879-1932 |
| Report of Chief Engineer U. S. Army | 1874-1906<br>1913-1931 |

It was voted "That the Society through the Library Committee apply for an Institutional Membership in the Special Libraries Association, said membership costing $15."

# PROCEEDINGS OF THE SOCIETY

## MINUTES OF MEETING

### Boston Society of Civil Engineers

April 16, 1947. A regular meeting of the Boston Society of Civil Engineers was held this date at Northeastern University as a joint meeting with the N.E. Section of the American Society of Civil Engineers.

The meeting opened at 6:00 P.M., with a catered dinner in the University Commons, which was attended by 144 persons of whom 138 were members.

The technical portion of the meeting was held in Room 228 N, and consisted of a paper entitled "Extension of Metropolitan District Water: What's Accomplished and What's Ahead", delivered by Karl R. Kennison, Chief Engineer, Metropolitan District Water Supply Commission. The paper was illustrated with numerous slides.

The arrangements for the meeting were made by the N.E. Section, A.S.C.E., and the meeting was presided over by Emil A. Gramstorff, President. In the absence of President Kinnison of the B.S.C.E., Vice-President Weaver represented the BSCE. Mrs. Frank E. Winsor, wife of the late Frank E. Winsor, Chief Engineer of the M.D.W.S.C., and Mrs. Karl R. Kennison, wife of the speaker of the evening were among the guests. A rising vote of appreciation was given Mrs. Winsor.

Approximately 170 persons attended the technical portion of the program.

The meeting adjourned at 9:00 P.M.

Edwin B. Cobb, *Secretary*

May 21, 1947.—A regular meeting of the Boston Society of Civil Engineers was held this date at Chipman Hall, Tremont Temple, Boston, Mass.

The meeting opened at 6:15 P.M., with a catered dinner which was attended by ninety seven members and guests.

A short business meeting was held at 7:30 P.M., at which time President Kinnison announced the death of the following members:—

> Alfred O. Doane who was elected a member April 20, 1910, and who died February 10, 1947.
>
> Wilfred A. Clapp who was elected a member June 17, 1896, and who died February 10, 1947.
>
> James L. Tighe who was elected a member October 20, 1897, and who died April 6, 1947.

The Secretary announced the election of the following member on this date:—

*Grade of Student*—Herbert W. Cohen

The technical portion of the meeting consisted of a symposium entitled "Engineering in the North".

President Kinnison introduced Mr. Carroll A. Farwell, member BSCE, partner in the firm of Fay, Spofford & Thorndike. Mr. Farwell outlined the symposium which described the design and construction of military airfields and bases in Newfoundland, Labrador, the Arctic and Alaska, for which his firm were the engineers. The following members of the staff of Fay, Spofford & Thorndike were introduced by Mr. Farwell and they described the particular phases of the projects in which they specialized.

Mr. William L. Hyland, member BSCE, described the location, overall features and climatic conditions at the various bases.

Mr. Howard J. Williams spoke on the structural features of the various projects.

Mr. Edward C. Keane described highway and runway problems.

Mr. Murray H. Mellish, member

BSCE, outlined the water supply and sewage disposal features of the projects.

The talks were all illustrated by lantern slides. Following a period of discussion the speakers were given a rising vote of thanks.

The meeting adjourned at 9:00 P.M.

Edwin B. Cobb, *Secretary*

## DESIGNERS' SECTION

April 9, 1947.—After dinner at the Old France Restaurant, Chairman Wyner called the meeting to order at 7:40 P.M. in Room 228, Northeastern University. The clerk's report of the last meeting was read and approved.

Chairman Wyner urged all present to obtain as many new members as possible in this, the 100th Anniversary Year.

He then called upon Professor Peabody to introduce the speaker, Mr. Charles S. Whitney, Consulting Engineer of Milwaukee and New York who spoke on the subject "Applications of the Plastic Theory to the Design of Modern Reinforced Concrete Structures". His talk was illustrated by lantern slides.

A short discussion period followed.

The meeting adjourned at 9:15 P.M.

Ninety-two members and guests attended.

R. W. Moir, *Clerk*

May 14, 1947.—After dinner at the Ambassador Restaurant, Chairman Wyner called the meeting to order at 6:55 P.M. in the Society Rooms, 715 Tremont Temple.

A short discussion was held relative to trying a new eating place. Several places were mentioned including Pattens and the Smorgasbord but no definite action was taken.

A motion was presented by Mr. O. G. Julian and seconded by Prof. Weaver "that the Board of Govt. of the Main Society be petitioned to change the name of the Designer's Section to Structural Section". This motion was amended to read "That the Executive Committee of the Designer's Secton give consideration to the choice of a more appropriate name for the section". The motion was passed as amended.

Chairman Wyner then introduced the speaker of the evening, Mr. Harrison E. Schock, Associate, of Kilham, Hopkins & Greeley, Boston, Mass., who spoke on the "Design of One of the Earliest Steel Frame Structures To Be Erected in Boston". The talk was illustrated with numerous lantern slides.

A brief discussion followed.

The meeting adjourned at 8:40 P.M.

Thirty-four members and guests attended.

R. W. Moir, Clerk

## TRANSPORTATION SECTION

April 23, 1947.—The Transportation Section of the Boston Society of Civil Engineers held a regular meeting at the Society Rooms on this date. An Executive Meeting was scheduled at 5:15 P.M. Six members were present at this meeting and an informal discussion was held on the tentative program for the coming year.

At 7:15 P.M. the Chairman, Professor George W. Hankinson introduced Mr. Edward C. Keane of Fay, Spofford & Thorndike, who gave a highly informative talk entitled "Review of Current Practice in Design of Subgrades for Runways and Highways". With the aid of slides, Mr. Keane discussed the contrasting standards and specifications used in subgrade and pavement design. The speaker developed his subject as a practical problem in soil mechanics. He described and compared the various methods of soil classification as established by different authorities. The problem of compaction methods and control was also discussed and illustrated.

Fifty-nine members and guests were present at the meeting.

Herman J. Shea, *Clerk*

## NORTHEASTERN UNIVERSITY SECTION

April 9, 1947.—The Chairman called the meeting to order at 7:15 P.M. The reading of reports was omitted. A business meeting was ordered to be held Wednesday, April 16, at 1:30 P.M., for the purpose of electing delegates to The Annual Conference. Attention was called to the joint meeting of the Northeastern Section A.S.C.E., and the Boston Society of Civil Engineers to be held on April 16, at the University Commons. A continuation of the Joint Program with the third in a series of six lectures to be conducted in room 440, Richard Hall, on April 22, at 5:00 P.M., was also announced.

The speaker of the evening was then introduced.

Mr. T. Alfred Fleming, Director of Conservation, Underwriter's Laboratories, spoke on "The Human Equation in Fire Prevention". In his talk he mentioned that last year was the most tragic year in fire losses both in property and life in the history of our country. He also explained that many lives are not lost by actually burning but by the breathing of super heated air which sears the lungs. Most of these deaths by super heated air could have been prevented by good engineering practices he explained. Many examples of recent costly fires and the faulty engineering that causes them were given.

In industrial processes he stressed the urgent need for a greater knowledge of chemistry. Examples of deadly fires due to the lack of chemical knowledge were cited.

Meeting adjourned at 8:30 P.M.

Louis W. Wise, *Acting Secretary*

April 16, 1947.—In the absence of the President, the Vice-President called the meeting to order promptly at 1:30 P.M., in the Society Room. A letter was read concerning the first meeting of a new section in the Boston Society of Civil Engineers, to be held in the Society Rooms, 715 Tremont Temple, April 30, 1947, at 7:00 P.M.

A discussion of the Annual Conference was conducted by the Secretary.

Election of two delegates was then conducted with nominations from the floor. Delegates elected are as follows:

Herbert W. Cohen
Jerome T. McCullough

Meeting adjourned at 1:55 P.M.

Louis W. Wise, *Acting Secretary*

## ADDITIONS

*Member*

Henry E. Bilodeau, 797 Bay Street, Taunton, Mass.

## DEATHS

Arthur A. Forbes, January 7, 1946
Adin M. Custance, June 22, 1946
Frank A. Barbour, May 27, 1947
Chester W. Smith, July 22, 1947

## APPLICATIONS FOR MEMBERSHIP

[July 15, 1947]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

*For Admission*

Nathaniel Clapp, Dover, Mass. (b. December 31, 1906, Greenfield, Mass.) Graduated from Worcester Polytechnic Institute 1929. Experience, served as field engineer, inspector and soil laboratory technician with City of Springfield, Mass., on Construction of Cobble Mountain Dam 1929 to 1933, then two months with Mass. Geodetic Survey; entered private practice in Palmer, Mass. in 1934 handling design and construction of municipal projects until 1939 when I joined the staff of Metcalf & Eddy, Boston, with whom I have served ever since, except for 1944 and 1945 during which I served with the Navy Civil Engineer Corps. Some of the projects on which I have served while with Metcalf & Eddy are as follows: 1939, Rock Creek Relief Sewer, Washington, D.C.; 1940, Boston M.D.C. relief sewers in charge of field surveys and borings for design studies; 1941, Bermuda Army Air Base design; 1942, Portland, Maine, surveys for sub-aqueous water mains, Wilmington, N.C. design and construction of army air field; 1943, preliminary studies and design of various water supply and sewerage projects. With the Navy C.E.C. was assigned to the Public Works Office, 7th Naval District, Miami, Florida about a year, then to the Sanitary Section of the Bureau of Yards & Docks in Washington, D.C. At present project engineer, Metcalf & Eddy, for the planning and design of various water supply and sewerage projects, and am now acting as resident engineer for the construction of an earth filled dam in Pittsfield, Mass. Refers to *E. B. Cobb, S. E. Coburn, S. Keith, F. A. Marston, J. W. Raymond, A. L. Shaw.*

William R. Cuff, South Braintree, Mass. (b. March 13, 1907, Braintree, Mass.) Graduated from Northeastern University in 1928 with degree of B.M.E. Construction engineer for the Western Union Telegraph Company, New York, prepared plans and specifications and supervised field construction until September, 1932. Attended Harvard Engineering School graduating June, 1933, with degree of S.M. in Civil Engineering. Experience, during 1934, supervised the field work for state wide traffic census for Mass. Department of Public Works. During 1935, U. S. Treasury, Procurement Division, as Commodity Chief in charge of purchasing of engineering materials and equipment. 1936-1942, employed as engineer with Hume Pipe Company of New England, duties included design, construction, sales and operation of concrete pipe plants in Maine, New Hampsire and Massachusetts. Entered active duty status Civil Engineering Corps, U.S. Navy, April, 1942, with rank of Lieutenant, ROinCC BuDocks CPFF Contracts Naval Dry Dock South Boston to October, 1942, construction totalling approximately $20,000,000. To November, 1944, ROinCC Seattle Tacoma Shipbuilding Corp., Tacoma, Washington, construction contracts approximately $17,000,000. Additional duty OinCC reinforced concrete floating dry dock construction, Olympia, Washington. To October, 1945, Contract Supt. and Ass. OinC Naval Supply Base, Stockton, California, construction cost approximately $35,000,000. Ordered to inactive duty October, 1945, with rank of Commander (CEC) USNR. November, 1945, returned to the Hume Pipe Company where now employed as engineer, having duties as previously described. Refers to *E. F. Childs, A. Haertlein, P. Holbrook, R. W. Horne, W. L. Hyland.*

S. Albert Kaufman, Tewksbury, Mass. (b. May 1, 1897, Miropol, Russia.) Graduated from Massachusetts Institute of Technology, class of 1919. Experience, chemist with Converse Rubber Company, Malden, Mass., from graduation at M.I.T. to Sept. 1919; calculator in the Steam Turbine division of the General Electric Company, Lynn, Mass., from Oct. 1919 to April, 1922; manufactured hosiery from April, 1922 to May, 1925, at Malden, Mass., Easton, Pa., and Gloversville, N. Y.; in private practice as land surveyor at Malden, Mass., 1925 to date, with exception of period Sept. 1942 to March 1943, in U.S. Army as military policeman being honorably discharged as private first class. Some of projects completed, while in private practice, Oil farm for State Fuel Co., East Boston, Mass.; Steel and concrete seating stands, Malden High School, Malden, Mass.; 1500 Beacon Street, Brookline, Mass.; Apartment Bldg., Brighton, Mass., Beth Israel Cemetery, Everett, Mass.; Land Court Surveys in Middlesex, Norfolk, Essex and Suffolk Counties. Publications, Article—India Rubber World, May 1, 1919; Technical Reports 14474, 14475 Steam Turbines for the G.E. Refers to *H. Estey, C. B. Humphrey, L. A. Chase* and *C. M. Anderson.*

Benjamin A. Lekesky, Boston, Mass. (b. October 20, 1914, Poquonock, Conn.) B.S. Civil Engineering, 1937, University of New Hampshire. Experience, Metropolitan District Water Supply Commission, field engineer, 1937-1940 assistant Resident engineer; 1940-1945, Bethlehem Steel Company, Quincy, Hingham, E. Boston Yards, senior engineer; 1945-1947, The Thompson & Litchner Company, Inc. Experience embodies a broad variety of construction work including water supply facilities, shipyard construction, field supervision of steel erecton, concrete control, building materials, etc. Firms which are familiar with my work include the following: Metcalf & Eddy, Engineers; Sawyer Construction Company; Aberthaw Company; Coolidge, Shepley, Bulfinch & Abbott; Perry, Shaw & Hepburn, Arch's; Gilbert Small & Company; George A. Fuller Company; Turner Construction Company; Ring Engineering Company; Foundation Company of New York and others. Refers to *M. N. Clair, R. W. Moir, H. G. Protze, S. E. Thompson.*

Richard W. Logan, West Medford, Mass. (b. January 20, 1895, Hoboken, New Jersey). Graduated from M.I.T. 1917 with degree in Mechanical Engineering. 1917-1919 served U.S. Army Coast Artillery Corps resigning commission as Captain in August, 1919. Experience, since September, 1919, with Chas. T. Main, Inc. Began work as tracer and draftsman and as I gained experience was trusted with design of smaller projects. During the course of the next 5 years became efficient enough to take over the entire design and specifications for smaller projects. Following some years spent in design and what is classified as sub-professional work, spent approximately 10 years in work which is classified as professional work as principal assistant on various engineering projects including the layout and design of industrial plants of various characters and especially the design of many textile mills in the cotton and woolen and worsted field. The last 5 to 6 years have spent in responsible charge both in the field and in the office of several projects for the U.S. Navy, including a shipyard constructed in Maine in 1941, and another shipyard constructed in Wilmington, Del., during the year 1942; the magnitude of these jobs may be indicated by the cost of this work, in the case of the Maine shipyard $8,000,000 and in the case of the Delaware shipyard approx. $14,000,000. On July 1, 1946, became a member of the firm of Chas. T. Main, Inc., where I am now located and have since been elected a director of the corporation. Am a registered professional engineer in the Commonwealth of Massachusetts. Refers to *A. W. Benoit, H. K. Barrows, S. Huckins, F. M. Gunby, W. F. Uhl.*

Eugene D. Mellish, Cambridge, Mass. (b. Sept. 11, 1923, East Brady, Pa.) Studied Chemical Engineering for

3½ semesters at Grove City College, Grove City, Pa. Withdrew from college January, 1943, and entered the Army February, 1943. May, 1943 was admitted to the Army Specialized Training Program studying Civil Engineering at New York University (9 months) and at University of Connecticut (6 months). February, 1946, was discharged from the Army and entered University of Connecticut that same month to study Civil Engineering. June, 1947, received B.S. degree. At present with Jackson & Moreland, Boston, Mass., designing draftsman in the structural department. Refers to *W. F. Condon, H. A. Gray, O. G. Julian, J. Lasker.*

Joseph G. Power, Boston, Mass. (b. October 21, 1916, Boston, Mass.) Graduated from Boston College in 1938, receiving B.S. degree in Physics. The prescribed course of studies placed much emphasis on advanced mathematics. Attended Lowell Institute at M.I.T., three years. The first two years were spent in completing the course in building construction and structural design and the last year in the supplementary surveying course; U.S. Engineer Office from Nov. 1941 to Feb. 1942, as rodman and transitman giving line and grade for heavy construction on harbor defense work; T. Stuart and Sons Company, from Feb. 1942 to July, 1942 on the additions to Hingham Ammunition Depot, served as rodman and transitman with field parties laying out building, sewers, roads and railroad trackage; Boston Elevated Railway, Sept. 1942 as transitman, and continuously employed by same to date, being assigned after six months to act as chief of a survey party and in June, 1944, was promoted to that grade. Duties required in present position include all preliminary calculations and research necessary for the successful conduct of all types of engineering surveys; the actual direction of the field work during the progress of these surveys; the making of maps, plans, profiles and studies based on these surveys; the calculation of traverses, land areas and quantities from the field notes and the design of alignments and fixing of grades. Refers to *A. J. Blackburn, C. E. Davis, A. F. McVarish, L. E. Moore, E. B. Myott.*

George R. Rich, Malden, Mass. (b. November 3, 1896, Worcester, Mass.) B.S. degree in Civil Engineering, Worcester Polytechnic Institute in 1919. Experience, 1919-1922, Structural Designer, Stone & Webster, steam hydro-electric and industrial plants; 1922-1925, Structural Designer, McClellan & Junkersfeld, Cahokia Steam Power Station; 1925-1928, Hydraulic Designer, Stone & Webster, Conowingo Hydro-electric Development; 1928-1929, structural engineer, Jackson & Moreland, Electrification Lackawanna Railroad; 1929-1931, Stone & Webster, Osage & Rock Island Hydroelectric Developments; 1931-1937, Hydraulic Engineer, War Department, improvements Cape Cod Canal, Fort Peck and Passamaquoddy Projects, Rehabilitation Boston Army Base, New England Flood Control; 1937-1941, Head Mechanical Engineer, in charge of Mechanical Engineering, all projects, TVA; 1941-1946, Chief Design Engineer TVA, in charge of design of all projects; 1946 to date, Hydraulic Engineer, Chas. T. Main, Inc., Hydro-electric and industrial developments. Refers to, *C. M. Allen, E. H. Cameron, B. O. McCoy, O. G. Julian, L. G. Ropes, B. Rose, W. F. Uhl.*

Ray L. Schoppe, Brookline, Mass. (b. May 13, 1889, Pittsburg, New Hampshire). Graduate of the University of Vermont in 1912 with degree of B.S. in C.E. Experience, June, 1912—April, 1913, instrumentman on R.R. construction with Canadian Pacific Railway; August, 1913 to date, Hydrographic and Geodetic Engineer with U.S. Coast and Geodetic Survey, holding Commissioned Rank since 1915. Service with this Bureau has been continuous except for war service in 1917-1919 with rank of Lieut. U.S.N.R. From 1913-1922, served as Junior Officer on various ships and shore parties engaged on "Combined Operations", which include Triangulation, Topography, Hydrography, Magnetics, and Astronomical Observations. Since 1922, have served practically all of the time as Officer in charge of various ships and other activities of this Bureau. This includes command of ships *Marinduque, Natoma, Bache, Ranger, Lydonia, Discoverer* and *Surveyor,* while working at various times in waters of the Atlantic, Gulf, and Pacific Coasts and in the Philippines and Alaska and the Aleutian Islands. It also includes 3 years as Dist. Supervisor at New Orleans and two years in charge of Magnetic Observatory at San Juan, P.R., and two years as Dist. Supervisor at Boston. Hold license (since 1928) as Master Mariner, unlimited tonnage, any ocean. Member of S.A.M.E. and A.S.C.E. At present, District Supervisor, in charge of the Northeastern District, U. S. Coast and Geodetic Survey, 10th Floor, Custom House, Boston, Mass. Now hold the rank of Captain, U.S.C. & G.S. Refers to *C. O. Baird, M. N. Clair, E. Harsch, E. N. Hutchins, H. B. Kinnison.*

Edward N. Smith, Boston, Mass. (b. May 28, 1914, Boston, Mass.) Graduated from Tufts College, B.S. in Civil Engineering, 1937. Experience, 1937-1941 several jobs including employment with Penn. R.R., N. Y. World's Fair, Wheeling Corrugating Company; 1941 to present, structural draftsman with Jackson & Moreland. Refers to *W. F. Condon, O. G. Julian, H. A. Gray, J. E. Lasker.*

Stephen H. Smith, Boston, Mass. (b. March 6, 1890, Bath-On-The-Hudson, N. Y.) Attended Cornell University, 1909-1913, degree of C.E. 1913. Experience, 1912-1923, employed by I. W. Jones, Consulting Engineer, Milton, N. H., tracer, principal engineer; 1923-1933, Stone & Webster, designer and resident engineer; 1933-1940, Federal P.W.A., engineer examiner, project engineer; 1940-1945, T.V.A., construction engineer; 1945 to date with Chas. T. Main Inc., engineer. Refers to *B. O. McCoy, C. T. Main, 2nd, L. G. Ropes, T. H. Safford and W. F. Uhl.*

---

### *Transfer from Grade of Junior*

Donald F. Libby, Everett, Mass., (b. July 24, 1909, Everett, Mass.) (Graduated from Northeastern University in 1931, with degree of B in Civil Engineering. Experience, employed by Commonwealth of Massachusetts Department of Highways for various periods from June, 1931, to January, 1937, on temporary appointment. Duties, figuring quantities, x-sections, final and preliminary estimating, final computing and entering final pit quantities. Received a permanent appointment July, 1937, which was terminated November, 1939, due to lack of funds. Appointed permanently in City of Everett Engineering Department, January, 1940, which has continued to present except for military service in U.S. Army from November, 1942 to November, 1945. -14 months service in the States and 22 months service European Theatre of Operations in Mapping Section, Office of Chief Engineer. Duties in Engineering Department, Everett, Mass., rodman, transitman, chief of party, lines & grades on streets, sewers, drains sidewalks, edgestones and all phases of city surveying, including drafting and computing. Refers to *H. B. Allen, C. O. Baird, L. A. Chase, J. Harmaala.*

Henry E. Weiss, Boston, Mass., (b. May 21, 1918, Brookline, Mass.) Graduated from Harvard University in 1941, majored in engineering sciences and also took a summer surveying course. Experience, continuously engaged in construction and engineering since graduation. Employed by Hew Construction

Company of Boston and is assistant Treasurer of W & L Engineering Company of Boston. 1943, junior engineer for Maurice A. Reidy at shipyard at Providence, R. I., as member of survey parties engaged in field layout work; 1944, field engineer for W & L Engineering company at Cleveland, Ohio, on construction of a drive-in-theatre. Assisted in supervision of construction of new roof for Boston Public Library, a new Armory at Norway, Maine, and recent alteration at Home Savings Bank, Boston. Holds A.B.C. Builders license in City of Boston. Member of Harvard Engineering Society. Refers to M. Avellino, A. Haertlein, J. Lasker, T. Mulcare, M. Linenthal.

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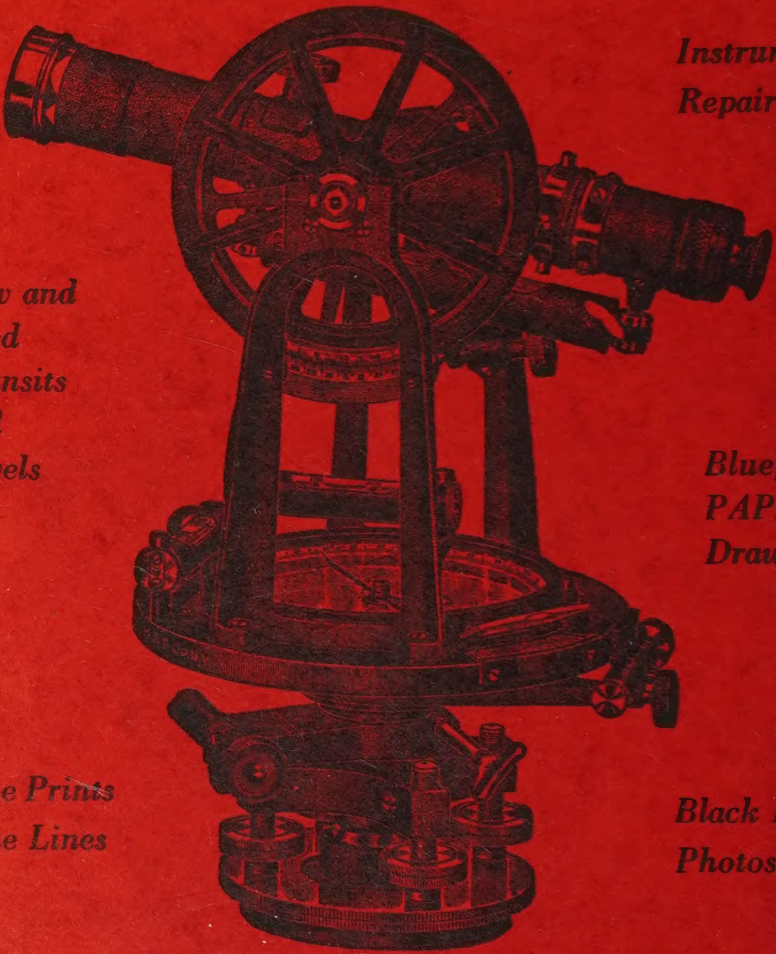

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